54367

Hydrogeologic Study and Design of Groundwater Abatement System at NL Industries, Inc. Pedricktown, New Jersey Plant Site

May 1983

GERAGHTY
& MILLER, INC.

Consulting Ground-Water Geologists and Hydrologists

NORTH SHORE ATRIUM
6800 JERICHO TURNPIKE
SYOSSET, NEW YORK 11791

NLI 001 0011

HYDROGEOLOGIC STUDY AND DESIGN
OF GROUNDWATER ABATEMENT SYSTEM
AT NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY PLANT SITE

May 1983

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6800 Jericho Turnpike
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HYDROGEOLOGIC STUDY

Introduction

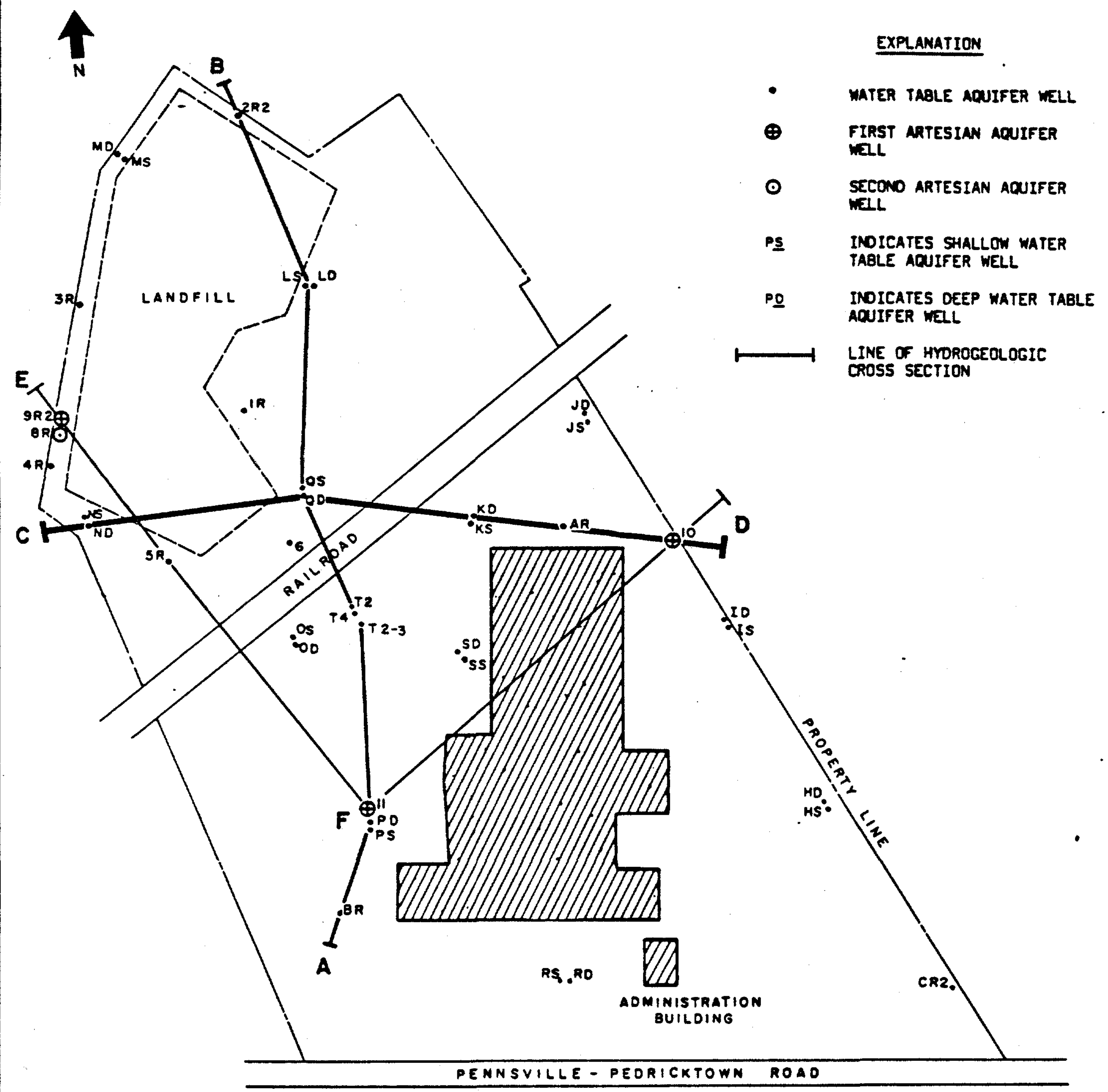
In July, 1982, Geraghty & Miller, Inc., was retained by NL Industries, Inc. to provide hydrogeological consulting services at the company's former plant located in Pedricktown, New Jersey.

During this investigation, Geraghty & Miller, Inc., reviewed hydrogeologic and water quality data from previous work carried out at the facility, installed 28 additional water-table observation wells, and two mandated wells into the first artesian aquifer. These 28 observation wells are in addition to the existing official monitoring wells which are being sampled quarterly in accordance with the consent order. As part of this field work, Shelby tube samples were obtained from the confining bed and analyzed for permeability. Water-levels were measured to prepare water-table maps and automatic water-level recorders were installed to determine the fluctuation of water levels in both the water table and first artesian aquifer.

In order to acquire aquifer parameter data for design of the abatement system, a controlled pumping test was carried out in the water-table aquifer.

Installation of Observation Wells

During the field investigation, 28 observation wells were screened in the water-table aquifer, and two deep wells were screened in the first artesian aquifer to determine hydrogeologic conditions. Figure 1 is a map of the plant site showing well locations and lines of section. Figure 2 shows



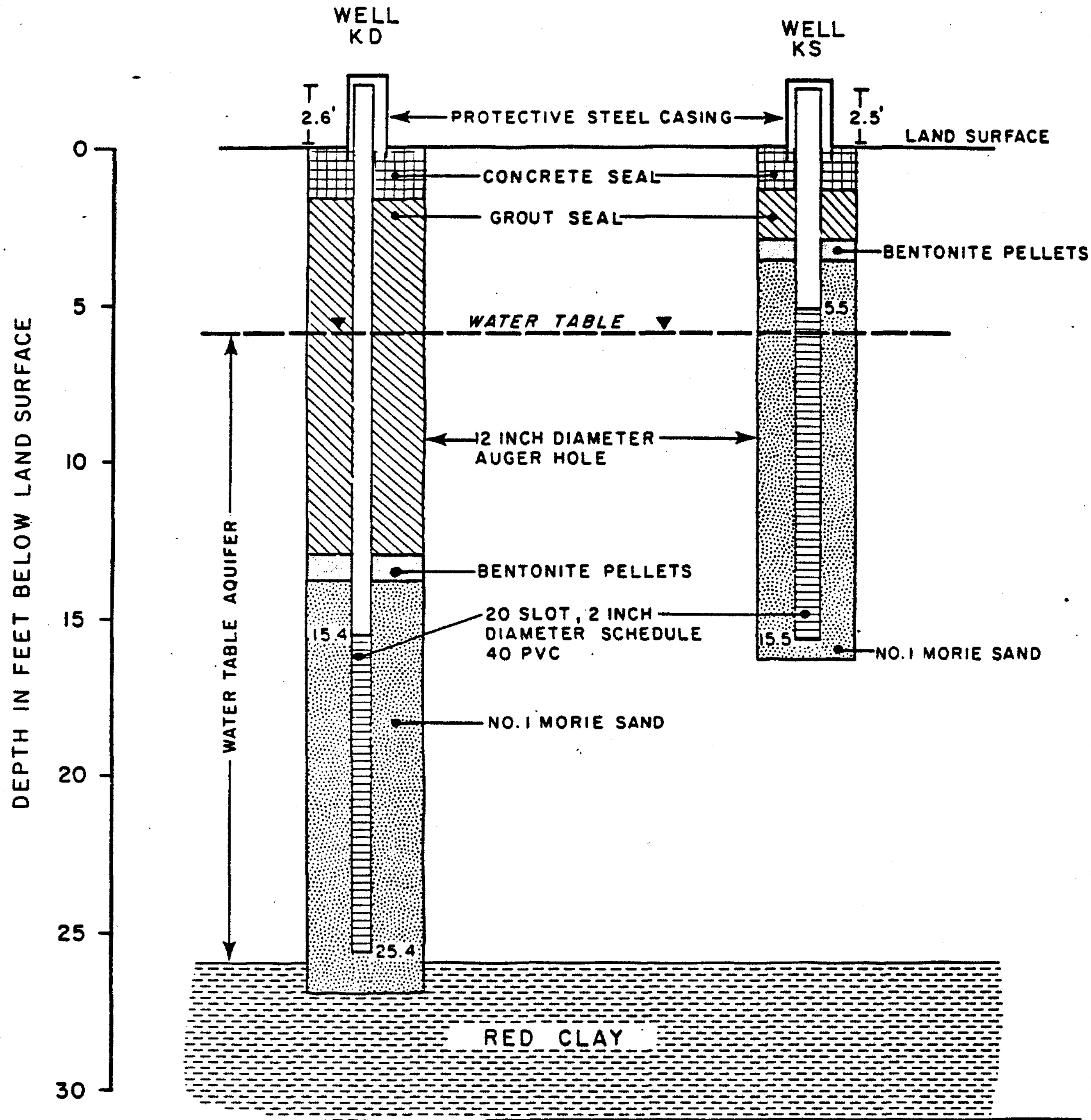
SUBJECT

WELL LOCATIONS AND LINES OF SECTION

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 1
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		



SUBJECT

TYPICAL OBSERVATION WELL CLUSTER
SCREENED IN WATER TABLE AQUIFER

PREPARED FOR

N.L. INDUSTRIES, INC.
PEDRICKTOWN, N.J.

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER PREPARED BY R. PADULA PROJECT MGR K. ATOBRAH	SCALE SHOWN DATE 4-83	FIGURE 2

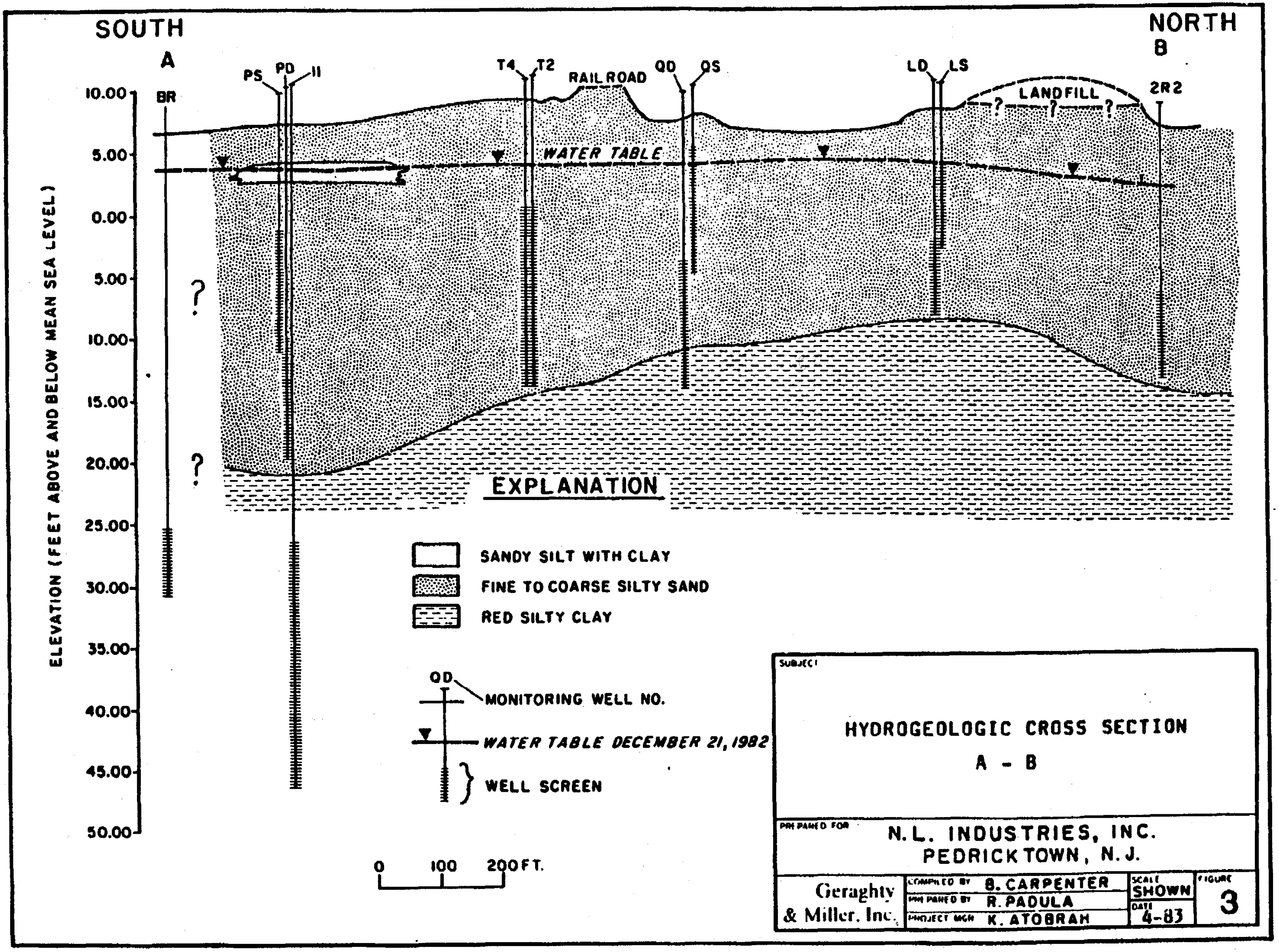
the construction details of a typical well cluster screened in the upper and lower zone of the water-table aquifer. Tables 1 and 2 provide construction details of the monitoring and observation wells. Geologic logs of the observation wells are included in Appendix A.

Testwell Craig Test Boring Company of Mays Landing, New Jersey, installed the wells with a power auger under Geraghty & Miller, Inc.'s direction. At each location, a 12-inch diameter hole was drilled to the required depth with split spoon samples collected at 5-foot intervals in wells completed in the lower water table zone. Shelby tube samples were collected from the confining clay layer, separating the water-table aquifer and the first artesian aquifer, at well locations T4 and 10. The results of laboratory permeability determinations of these samples are provided in Appendix C. The elevation of each well (top of PVC casing) was surveyed and converted to mean sea level by Albert A. Fralinger, of Bridgeton, New Jersey.

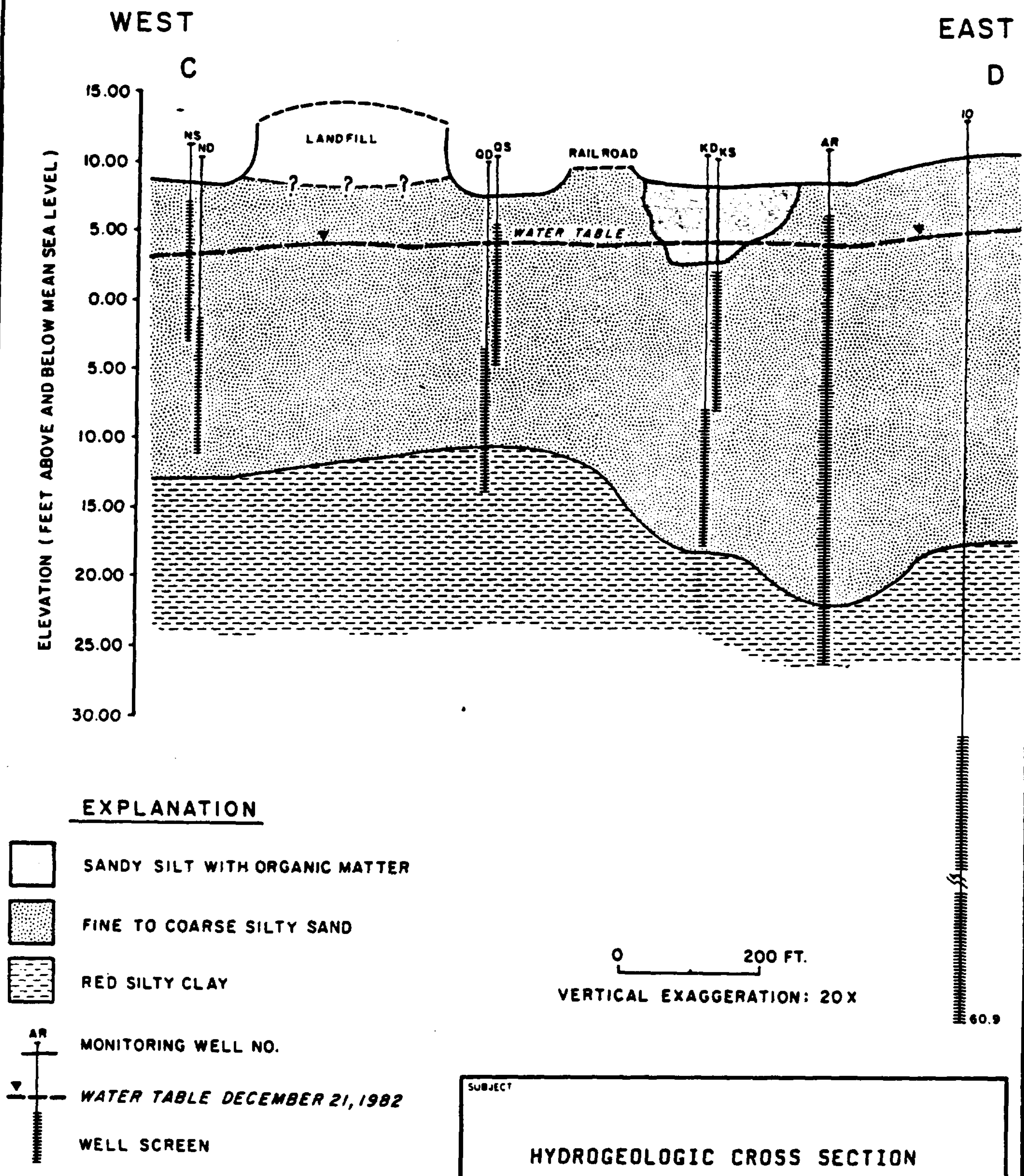
Hydrogeologic Framework

Based on geologic logs obtained from monitoring and observation wells, three hydrogeologic cross-sections were prepared to show groundwater conditions at the site. Figure 3 illustrates hydrogeologic conditions in a south-to-north direction, and Figure 4 shows conditions in a west-to-east direction. Figure 5 illustrates the position of the first artesian aquifer in relation to the water table aquifer.

There are three main geologic units, namely, a) the water-table aquifer, b) the first confining clay layer, and c) the first artesian aquifer.


SOUTH
A
NORTH
B
BR
PS
PD
11
T4
T2
RAILROAD
QD
QS
LD
LS
LANDFILL
2R2
WATER TABLE
ELEVATION (FEET ABOVE AND BELOW MEAN SEA LEVEL)
10.00
5.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
EXPLANATION
SANDY SILT WITH CLAY
FINE TO COARSE SILTY SAND
RED SILTY CLAY
QD
MONITORING WELL NO.
WATER TABLE DECEMBER 21, 1982
WELL SCREEN
0
100
200 FT.
SUBJECT
HYDROGEOLOGIC CROSS SECTION
A - B
PREPARED FOR
N.L. INDUSTRIES, INC.
PEDRICKTOWN, N.J.
Geraghty & Miller, Inc.
COMPILED BY B. CARPENTER
PREPARED BY R. PADULA
PROJECT MGR K. ATOBRAH
SCALE SHOWN
DATE 4-83
FIGURE 3

NLI 001 0021



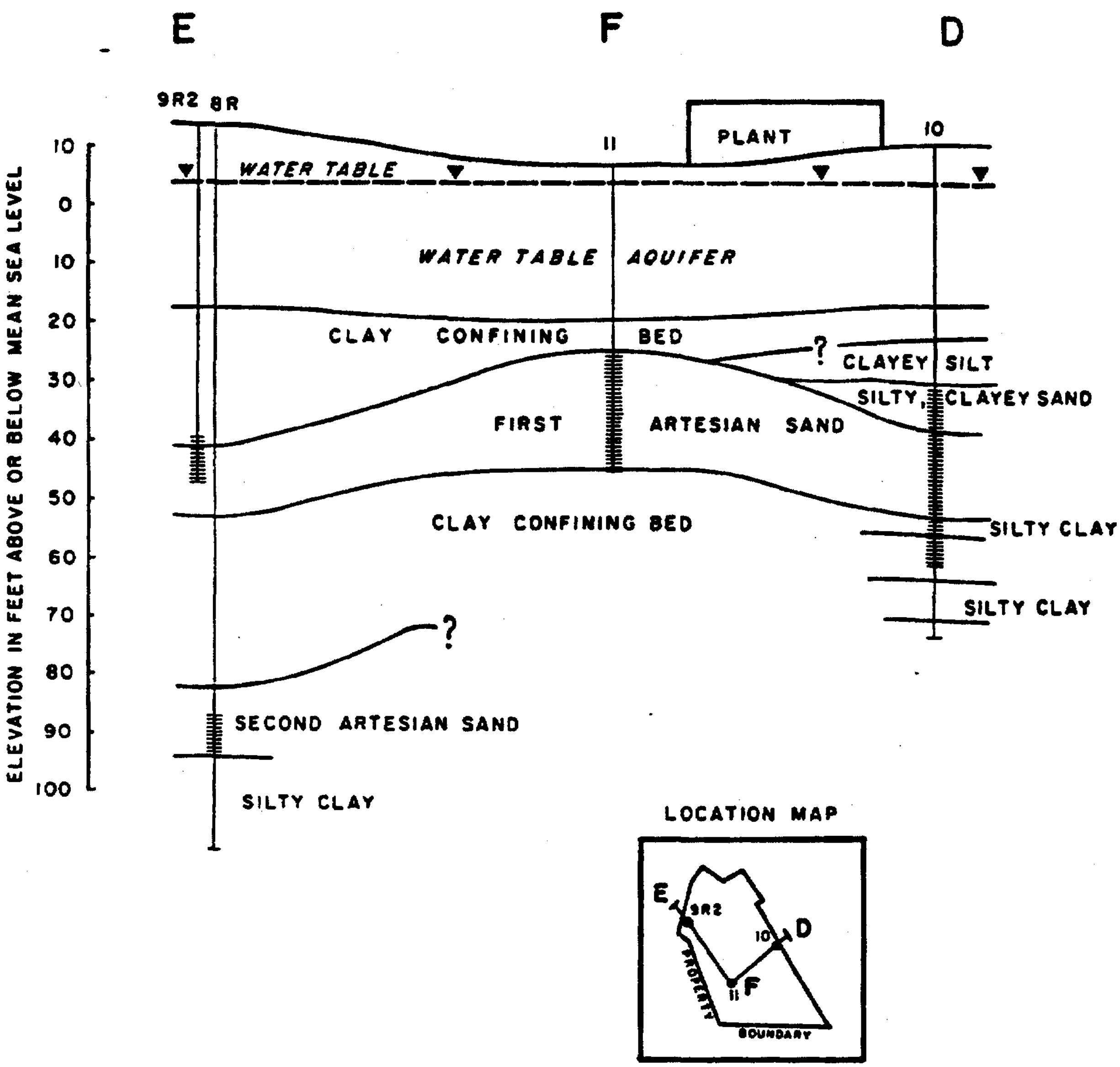
SUBJECT

HYDROGEOLOGIC CROSS SECTION
C - D

PREPARED FOR

N.L. INDUSTRIES, INC.
PEDRICKTOWN, N.J.

Geraghty & Miller, Inc.	COMPILED BY	B. CARPENTER	SCALE SHOWN	FIGURE 4
	PREPARED BY	R. PADULA	DATE 4-83	
	PROJECT MGR	K. ATOBRAH		



SUBJECT

HYDROGEOLOGIC CROSS SECTION
E - F - D

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N.L. INDUSTRIES, INC.
PEDRICKTOWN, N.J.

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER		SCALE SHOWN	FIGURE 5
	PREPARED BY R. PAOULA		DATE 4-83	
	PROJECT MGR K. ATOBRAH			

Table 1. Construction Details of Official Monitoring Wells at NL Industries, Pedricktown New Jersey, Plant Site.

Well No.	Elevation of Measuring Point (feet above mean sea level)	Total Depth Drilled (feet below land surface)	Screened Interval (feet below land surface)	Height of Measuring Point (feet above land surface)	Screen Slot Size (thousandths of an inch)
1R	13.32	35.5	4 - 32	4.0	20
2R2	9.14	25	13 - 20	2.2	20
3R	14.10	33	4 - 33	2.7	20
4R	14.80	29	9 - 21	2.7	20
5R	10.03	35.5	7 - 16	2.0	20
6	12.23	21.5	11 - 21	2.5	40
8R	16.55	124.5	101 -108	2.9	18
9R2	16.73	73	53 - 61	2.8	18
AR	11.39	34.5	2.5- 32.5	2.5	20
BR	8.88	45	31 - 37	2.3	18
CR2	15.96	45	25 - 31	2.8	20
10	13.72	82	42.0-72.0	2.0	20
11	9.25	59	33.2-53.2	1.8	20

Note: All wells are 4-inch diameter.

Table 2. Construction Details of Observation Wells Installed in November--December 1982, at NL Industries, Pedricktown, New Jersey Plant Site.

Well No.	Elevation of Measuring Point (feet above mean sea level)	Total Depth Drilled (feet below land surface)	Screened Interval (feet below land surface)	Height of Measuring Point (feet above land surface)
HD	16.73	41	23.8 - 38.8	2.6
HS	16.83	25	9.4 - 24.4	2.6
ID	15.24	42	18.6 - 33.6	2.6
IS	15.41	16	5.5 - 15.5	2.5
JD	12.08	27	15.1 - 25.1	2.9
JS	11.95	15	4.4 - 14.4	2.6
KD	10.70	29	15.4 - 25.4	2.6
KS	10.51	16	5.5 - 15.5	2.5
LD	10.89	19	9.7 - 16.7	2.3
LS	10.74	11	3.9 - 10.9	2.1
MD	8.37	19	9.6 - 17.6	2.0
MS	9.83	10	3.2 - 10.2	2.8
ND	10.35	22	11.9 - 21.9	2.1
NS	11.30	14	4.2 - 14.2	2.6
OD	11.44	37	19.5 - 34.5	3.0
OS	10.92	20	3.8 - 18.8	2.2
PD	10.25	30	16.8 - 26.8	3.2
PS	9.14	18	7.9 - 17.9	2.1
QD	10.19	25	11.5 - 21.5	2.5
QS	10.52	13	2.4 - 12.4	2.6
RD	13.62	41	25.0 - 35.0	2.0
RS	13.84	20	5.0 - 20.0	2.0
SD	11.45	30	15.0 - 27.0	2.5
SS	10.76	15	5.0 - 15.0	2.0
T2	11.34	27	7.6 - 22.6	2.4
T4*	11.09	23	8.0 - 23.0	2.0

*) 4-inch diameter schedule 80 PVC screened with 20 slot.

The water-table aquifer is part of the Cape May Formation and is comprised of fine-to-coarse, silty sand. Its thickness is about 15 to 25 feet.

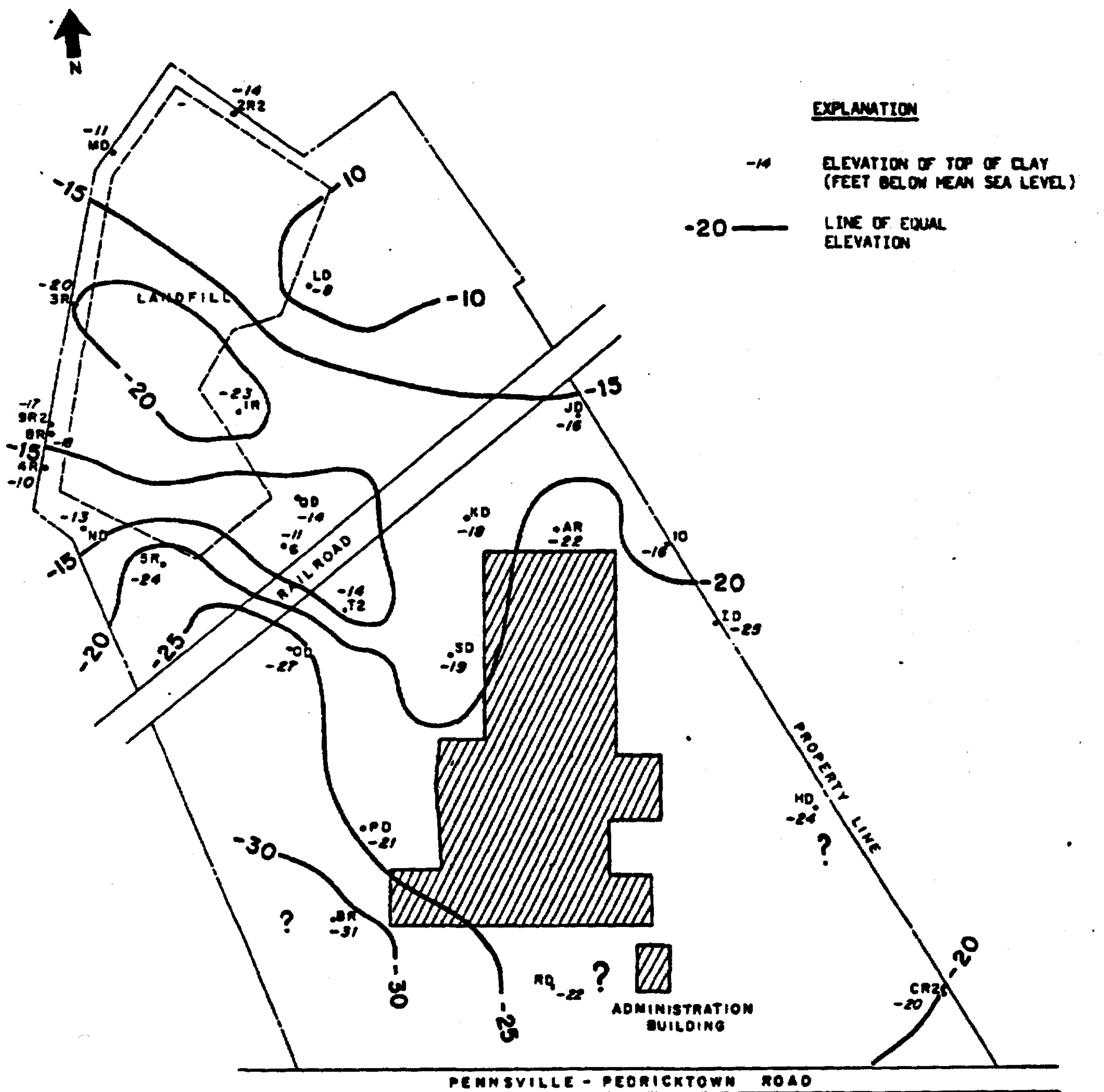
The first confining clay layer is a member of the Raritan Formation, and is perhaps equivalent to the Merchantville-Woodbury confining bed. The unit is comprised of red and white clay occasionally mottled with silt. As shown in Figure 6, the clay bed occurs at elevations of 10 to 30 feet below mean sea level. Its thickness ranges from 10 to 20 feet (Figure 7).

The thickness of the clay layer in the southern portion of the site, in particular around Well 11 and BR, cannot be clearly defined from existing geologic logs. It would be advisable to clarify stratigraphic conditions in this area by gamma-ray geophysical logging of existing wells and, if needed, installation of a few additional test borings.

The first artesian aquifer is found below the clay confining bed at elevations of 16 to 48 feet below mean sea level. This aquifer is a sand unit of the Magothy-Raritan Formation. Its thickness, based on records from three wells (9R2, 10, and 11), ranges from 10 to 30 feet (Figure 8).

Groundwater Flow

Several rounds of water-level measurements were taken in the December, 1982 to January, 1983 period. Little water-level fluctuation occured during this period and the January, 1983 measurements have been utilized in this report. Water-level elevations measured on January 11, 1983 in wells tapping the upper water-table aquifer are shown in Figure 9. As shown, the general direction of groundwater flow at the site is towards the west. A



0 100 200 300 FEET

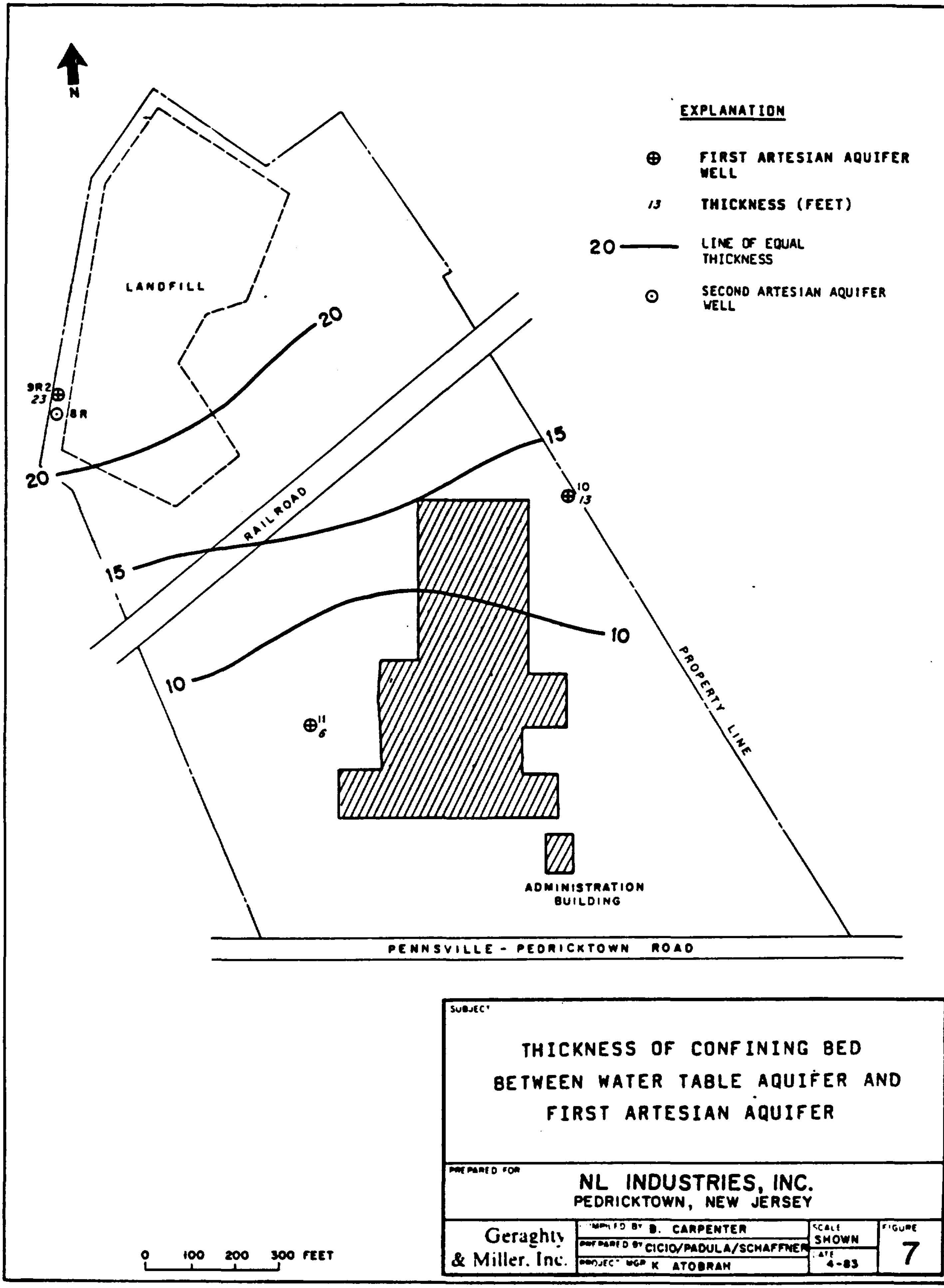
SUBJECT

CONTOURS ON TOP OF THE UPPERMOST CLAY CONFINING BED

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 6
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		



SUBJECT

THICKNESS OF CONFINING BED BETWEEN WATER TABLE AQUIFER AND FIRST ARTESIAN AQUIFER

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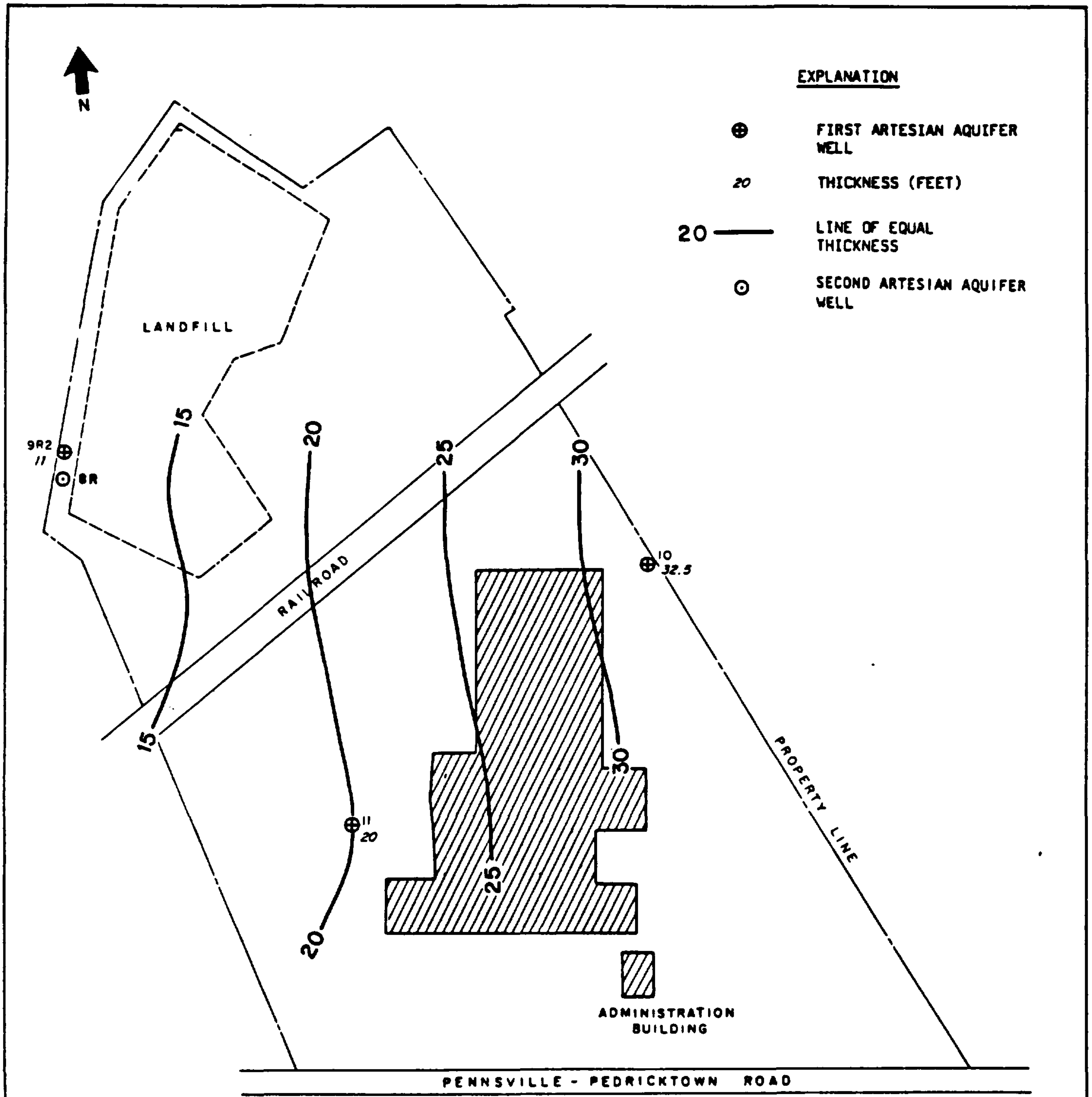
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.

COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 7
PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
PROJECT MGR K ATOBRAH		



0 100 200 300 FEET

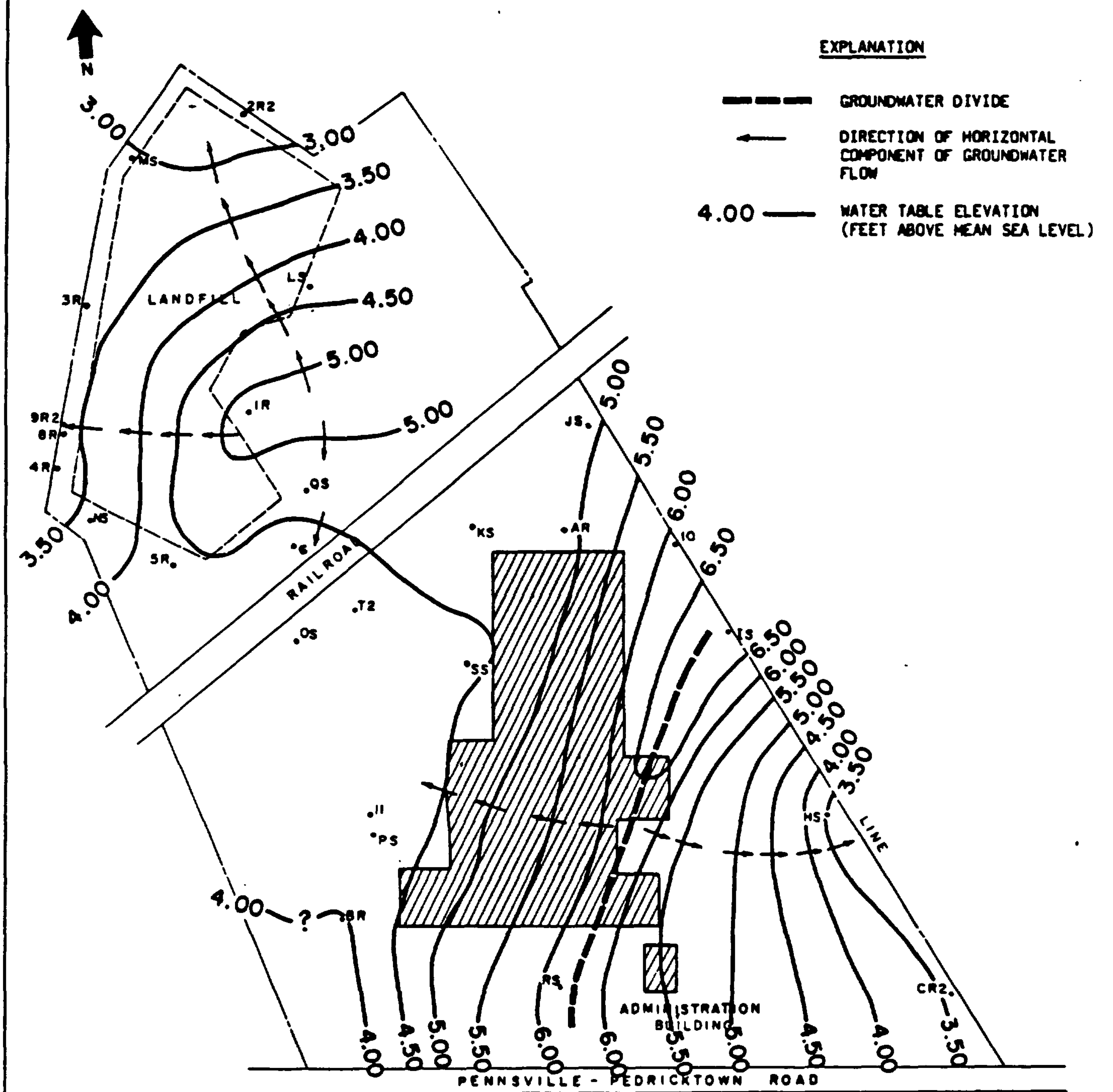
SUBJECT

THICKNESS OF THE FIRST ARTESIAN AQUIFER

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 8
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		



SUBJECT

CONTOURS ON THE WATER TABLE
JANUARY 11, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER PREPARED BY CICIO/PADULA/SCHAFFNER PROJECT MGR K. ATOBRAH	SCALE SHOWN DATE 4-83	FIGURE 9

NLI 001 0030

groundwater divide has been mapped at the southern end of the property and groundwater flows towards the east and west in this area.

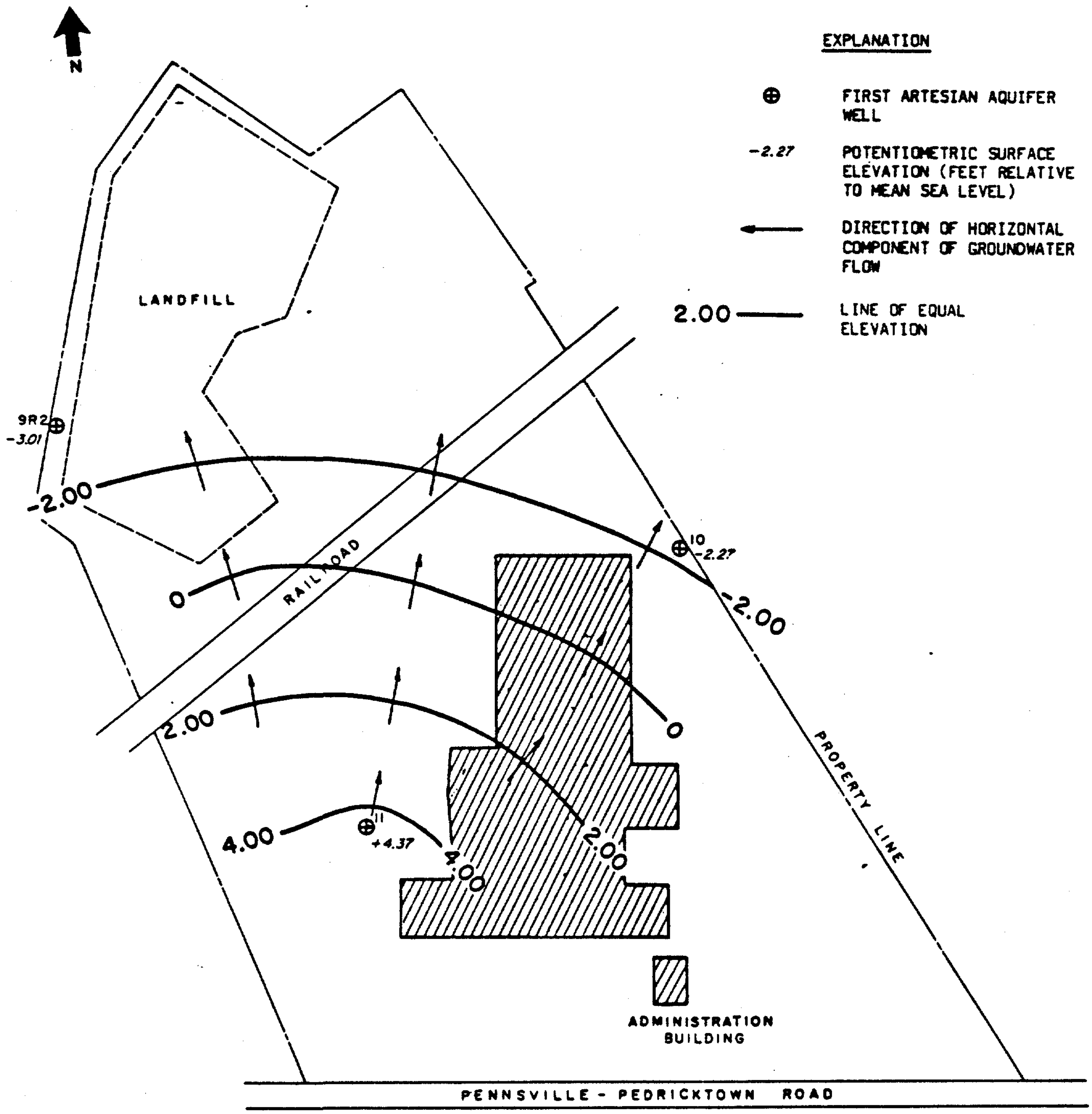
The water-level elevation in the upper and lower horizons of the water-table aquifer are generally the same, except in cluster wells I and R, both of which have head differences of about 2.0 feet.

These head differences may reflect local perched conditions but do not affect ground-water flow directions nor the position of the water-table divide shown on Figure 9.

At the northern end of the property where the lined landfill is located, groundwater movement is towards the north. In the central portion of the site, groundwater appears first to move towards the former marsh area and then in a westerly direction.

Water-level elevations indicating the potentiometric pressure in the first artesian aquifer on January 11, 1983 are shown in Figure 10. The groundwater flow direction is towards the north and the north-northeast, probably reflecting nearby industrial pumpage from the Magothy Raritan aquifer. A summary of water-level data collected appears in Table 3.

Comparing the elevation of the water table with that of the first artesian aquifer (Table 4), it was found that heads in the water table are greater than those in the artesian aquifer, except at Well 11. At the latter site the head in the artesian aquifer is slightly above that of the water table. These vertical flow conditions are illustrated in Figure 11.



0 100 200 300 FEET

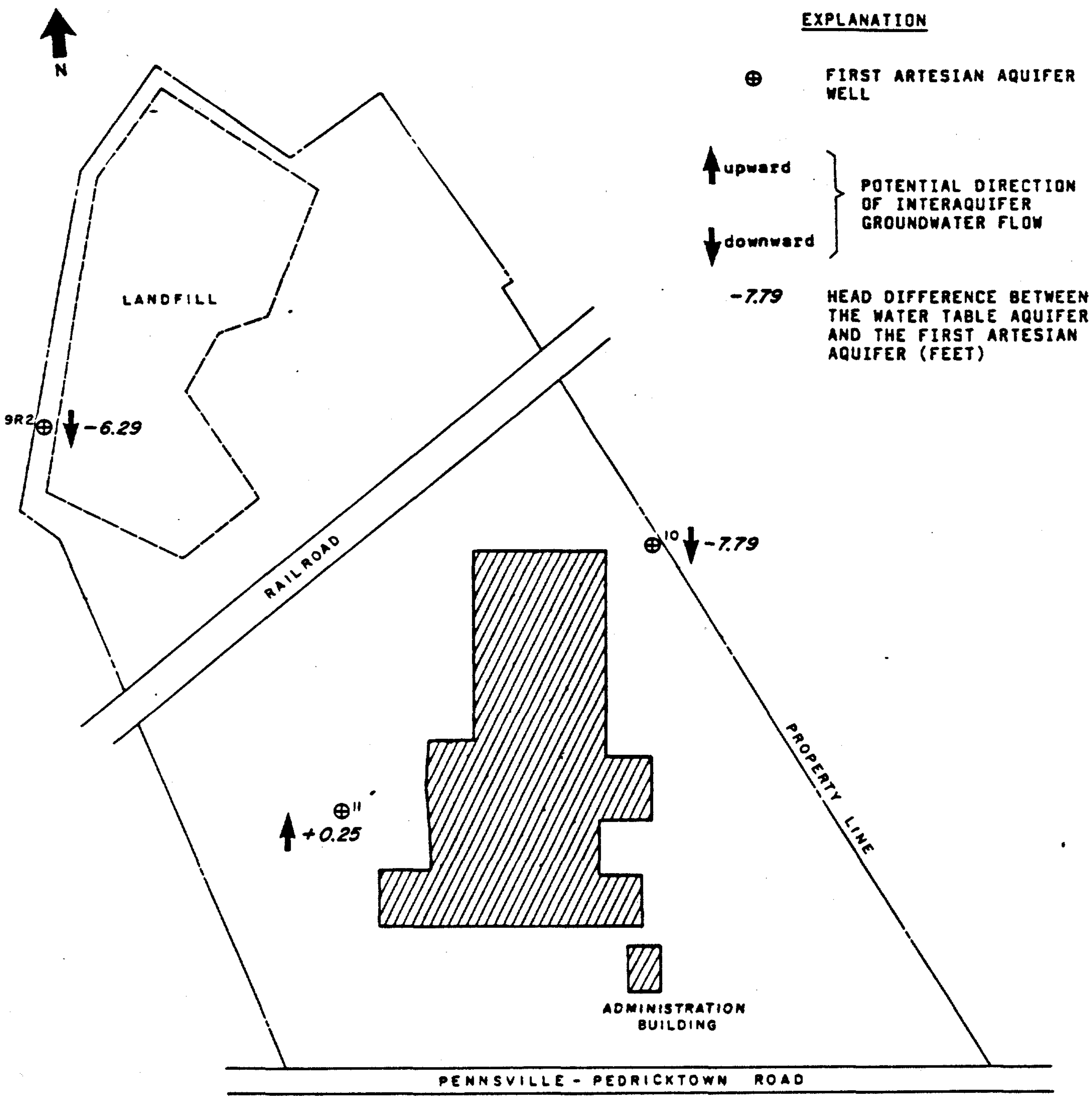
SUBJECT

POTENTIOMETRIC SURFACE OF FIRST ARTESIAN AQUIFER
JANUARY 11, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 10
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		



SUBJECT

HEAD DIFFERENTIAL BETWEEN WATER TABLE AQUIFER AND FIRST ARTESIAN AQUIFER
JANUARY 11, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 11
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		

Table 3. Summary of Water-Level Elevation Data, NL Industries, Pedricktown, New Jersey.

Well No.	Elevation of Measuring Point	Water-Level Elevation (feet above or below mean sea level) 12-9-82	12-15-82	12-21-82	12-28-82	1-6-83	1-11-83	3-8-83
1R	13.32	4.60	4.56	4.87	4.84	4.89	5.22	6.27
2R2	9.14	2.31	2.32	2.48	2.50	2.58	2.71	3.22
3R	14.10	2.83	2.85	3.02	3.03	3.09	3.20	-
4R	14.80	3.08	3.06	3.24	3.27	3.23	3.28	4.21
5R	10.03	3.39	3.33	3.65	3.57	3.87	4.36	5.77
6	12.23	3.77	3.74	3.96	3.91	4.03	4.36	4.78
8R	16.55	-8.63	-6.38	-8.35	-8.49	-6.95	-7.82	-2.99
9R2	16.73	-3.52	-2.77	-3.42	-3.25	-2.60	-3.01	6.50
10	13.72	-2.68	-2.30	-2.48	-2.23	-2.18	-2.27	-2.00
11	9.25	4.77	3.80	4.00	4.04	4.17	4.37	5.01
AR	11.39	4.14	4.13	4.36	4.39	4.44	4.62	6.45
BR	8.88	3.46	3.46	3.66	3.68	3.83	3.99	4.68
CR2	15.96	2.75	2.88	3.07	3.27	3.39	3.39	-
HD	16.73	2.75	2.86	3.04	3.25	3.37	3.38	-
HS	16.83	2.78	2.87	3.05	3.26	3.36	3.37	-
ID	15.24	4.05	4.04	4.24	4.35	4.34	4.45	6.39
IS	15.41	6.42	6.46	6.68	6.82	6.82	6.99	9.74
JD	12.08	4.29	4.20	4.55	4.48	4.54	4.86	6.58
JS	11.95	4.29	4.24	4.57	4.54	4.57	4.88	-
KD	10.70	3.98	3.98	4.22	4.22	4.31	4.57	6.08
KS	10.51	4.06	4.09	4.31	4.32	4.38	4.66	6.18
LD	10.89	3.76	3.74	4.06	4.00	4.00	4.23	5.53
LS	10.74	3.81	3.77	4.14	4.09	4.08	4.40	5.84
MD	8.37	2.45	2.51	2.69	2.70	2.77	2.88	3.51
MS	9.83	2.54	2.56	2.71	2.73	2.82	3.07	3.55
ND	10.35	3.15	3.09	3.32	3.27	3.41	3.62	4.23
NS	11.30	3.17	3.14	3.37	3.33	3.44	3.63	4.30
OD	11.44	3.46	3.44	3.65	3.58	3.74	4.09	4.51
OS	10.92	3.58	3.54	3.78	3.71	3.84	4.22	4.70
PD	10.25	3.63	3.65	3.80	3.80	3.92	4.11	4.72
PS	9.14	3.63	3.65	3.80	3.80	3.93	4.12	4.72
QD	10.19	3.89	-	4.17	4.14	4.24	4.57	5.48
QS	10.52	3.96	3.94	4.19	4.19	4.27	4.61	5.54
RD	13.62	4.33	4.90	5.09	5.23	4.74	4.66	6.88
RS	13.84	5.68	5.64	5.91	5.99	5.99	6.22	7.46
SD	11.45	3.66	3.72	3.92	3.97	3.83	4.07	5.29
SS	10.76	3.90	3.89	4.08	4.14	4.17	4.38	-
T2	11.34	3.79	3.77	4.00	3.97	4.05	4.39	5.42
T4	11.09	3.77	3.79	3.99	3.94	4.01	4.37	5.06

Note: All wells measured from top of PVC

Table 4. Water-Level Elevation and Head Differential Between Water-Table Aquifer and First Artesian Aquifer in Wells 10, 11, and 9R2 (in feet), NL Industries, Pedricktown, New Jersey.

Date	Well 10	Water-Level Elevation Cluster I[1)]	Head Differential
12- 9-82	-2.68	5.23	-7.91
12-15-82	-2.30	5.25	-7.55
12-21-82	-2.48	5.46	-7.94
12-28-82	-2.23	5.59	-7.82
1- 6-83	-2.18	5.58	-7.76
1-11-83	-2.27	5.72	-7.99
3- 8-83	-2.00	8.17	-10.17

Date	Well 11	Cluster P[1)]	Head Differential
12- 9-82	3.65	3.63	0.02
12-15-82	3.80	3.65	0.15
12-21-82	4.00	3.80	0.20
12-28-82	4.04	3.80	0.20
1- 6-83	4.17	3.93	0.24
1-11-83	4.37	4.12	0.25
3- 8-83	5.01	4.72	0.29

Date	Well 9R2	Well 4R	Head Differential
12- 9-82	-3.52	3.08	-6.60
12-15-82	-2.77	3.06	-5.83
12-21-82	-3.42	3.24	-6.66
12-28-82	-3.25	3.27	-6.52
1- 6-83	-2.60	3.23	-5.83
1-11-83	-3.01	3.28	-6.29

1) An average water-level elevation was calculated between the deep and shallow water levels in the well cluster.

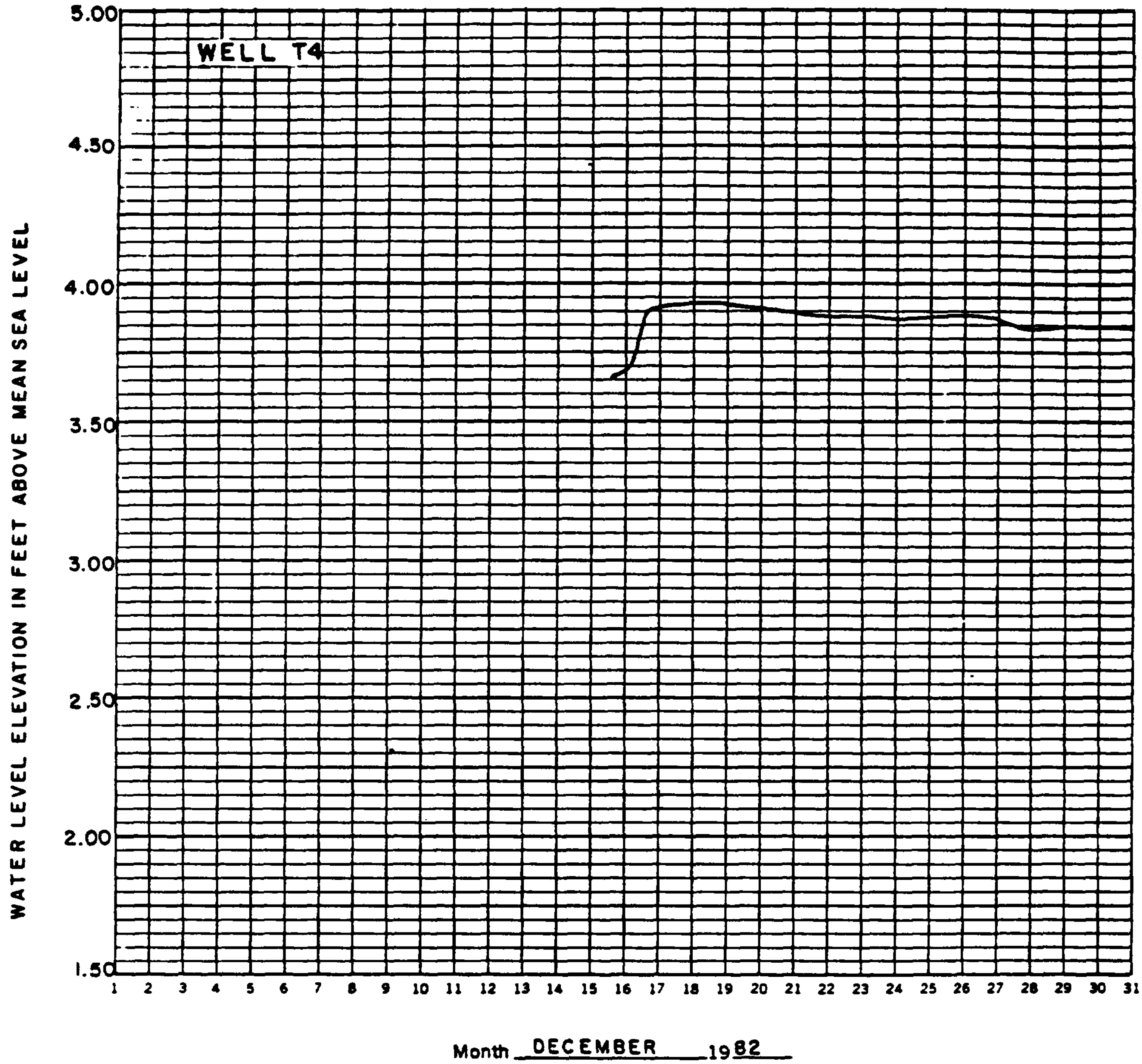
In order to monitor water-level fluctuation at the site, automatic water-level recorders were placed on Wells T4, 10, and 11. Well T4 is screened in the water table and both Wells 10 and 11 are screened in the first artesian aquifer. As shown on the hydrographs of Well T4 (Figures 12 and 13), the water table rose about 0.5 feet in the period December, 1982 to January, 1983.

The hydrograph of Well 10 (Figure 14) shows a 2 feet decline in potentiometric pressure during January, 1983, presumably a reflection of nearby industrial pumpage. The hydrograph of Well 11 (Figure 15) showed little water-level fluctuation during the second half of December, 1982.

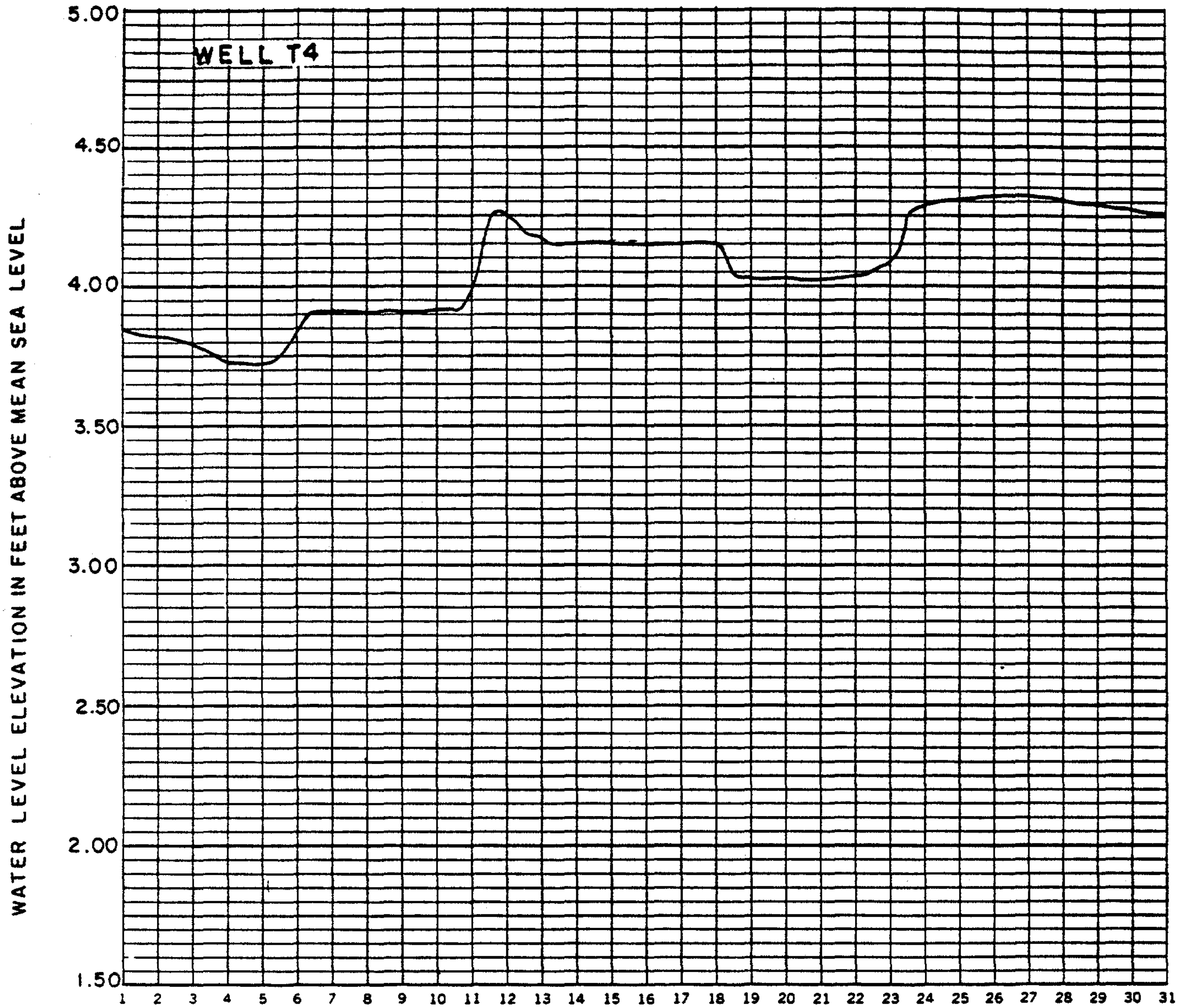
Hydraulic Parameters

The hydraulic parameters for the various geologic units at the sites are summarized in Table 5. A 24-hour controlled pumping test was conducted in Well T4 on March 7 and 8, 1983 to obtain the hydraulic parameters of the water-table aquifer. Two observation wells (T2-2 and T2-3) were installed close to the pumping well T4 to measure water-level drawdown during the pumping test. These wells are fully screened in the water-table aquifer. Pumping test data and graphs showing drawdowns of the water level with time are included in Appendix B.

The parameters in the confining clay layer were derived from laboratory analysis of samples from Shelby tubes (see Appendix C). Laboratory results indicate that the clay confining bed has a vertical hydraulic conductivity in the range of 7.11×10^{-5} ft/day (2.5×10^{-8} cm/s) to 1.91×10^{-4} ft/day (6.73×10^{-8} cm/s). The average horizontal hydraulic conduc-



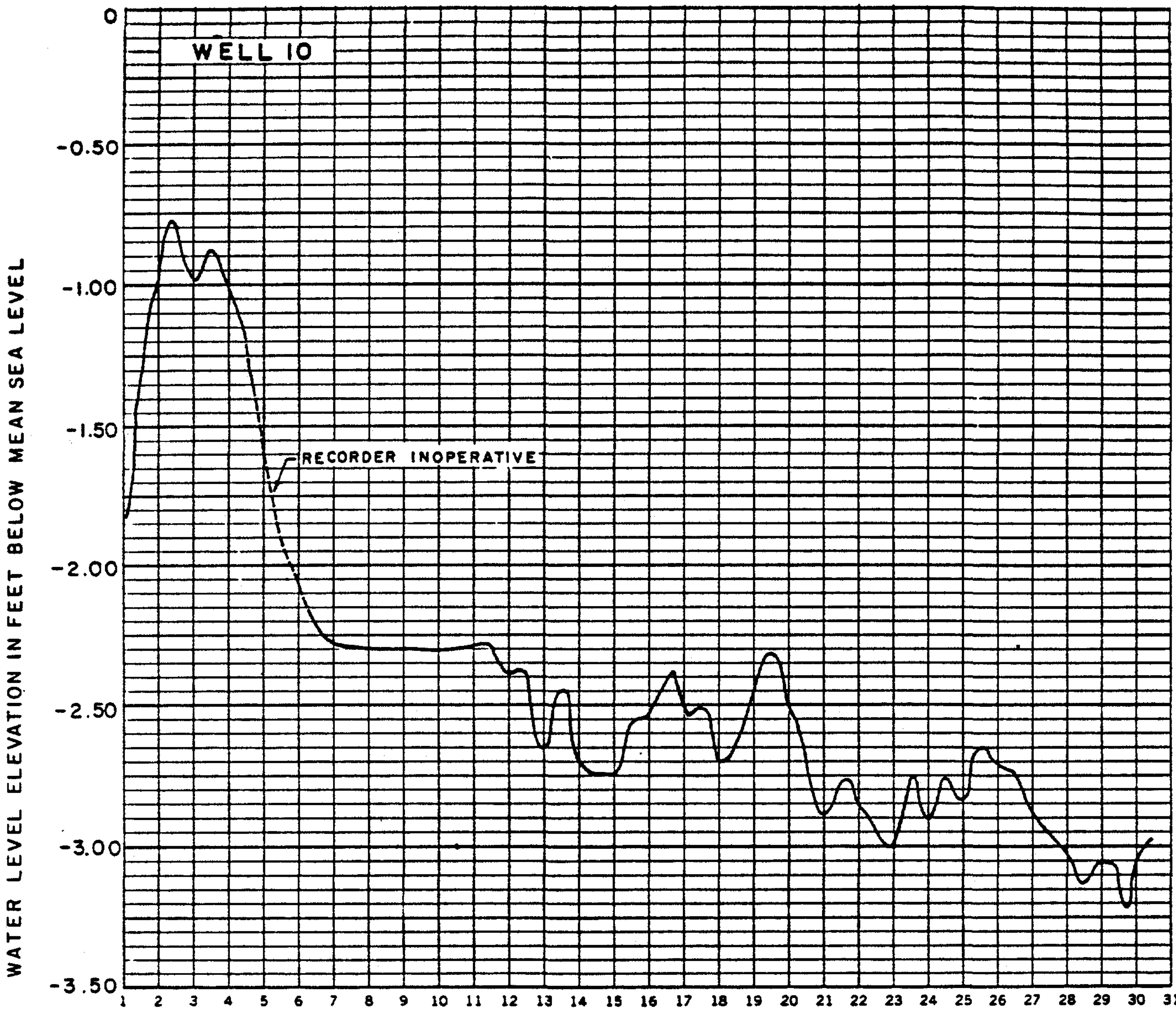
SUBJECT: HYDROGRAPH OF WELL T4 — WATER TABLE AQUIFER DECEMBER, 1982			
PREPARED FOR: NL INDUSTRIES, INC. Pedricktown, N.J.			
Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER PREPARED BY E. WILSON PROJECT MGR K. ATOBRAH	SCALE SHOWN DATE APRIL 83	FIGURE 12



Month JANUARY 19 83

SUBJECT HYDROGRAPH OF WELL T4 WATER TABLE AQUIFER JANUARY, 1983			
PREPARED FOR N L INDUSTRIES, INC. Pedricktown, N.J.			
Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER PREPARED BY E WILSON PROJECT MGR K. ATOBRAH	SCALE SHOWN DATE APRIL 83	FIGURE 13

NLI 001 0038



Month JANUARY 1983

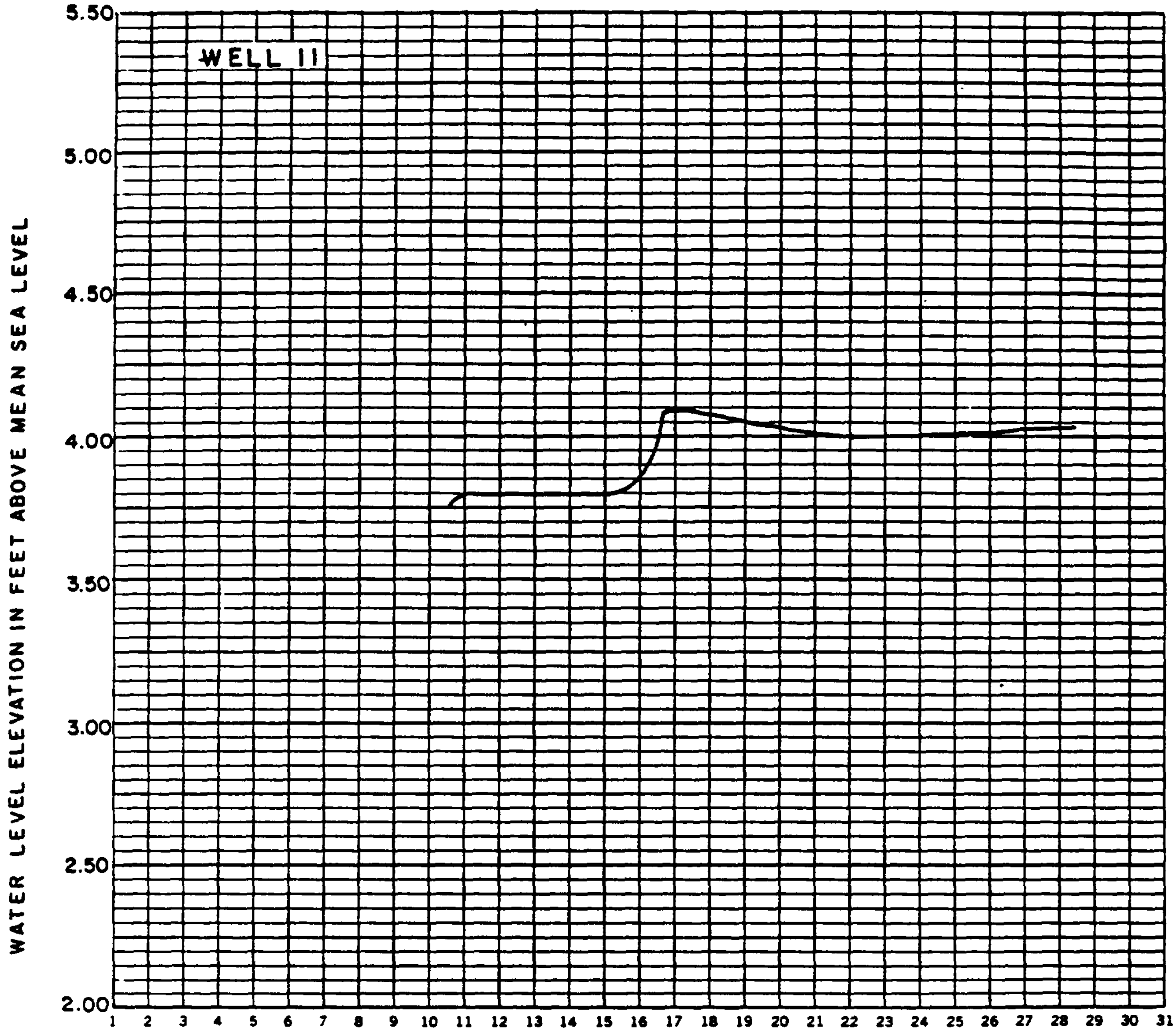
SUBJECT

HYDROGRAPH OF WELL 10

FIRST ARTESIAN AQUIFER
JANUARY, 1983

PREPARED FOR N L INDUSTRIES, INC.
Pedricktown, N. J.

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER PREPARED BY E. WILSON PROJECT MGR K. ATOBRAH	SCALE SHOWN DATE APRIL 83	FIGURE 14



Month DECEMBER 19 82

SUBJECT

HYDROGRAPH OF WELL 11

FIRST ARTESIAN AQUIFER

DECEMBER, 1982

PREPARED FOR

NL INDUSTRIES, INC.

Pedricktown, N.J.

Geraghty & Miller, Inc.	COMPILED BY	B.CARPENTER	SCALE SHOWN	FIGURE 15
	PREPARED BY	E.WILSON	DATE APRIL 83	
	PROJECT MGR	K.ATOBRAH		

Table 5. Hydraulic Parameters of Geologic Units at the NL Pedricktown, New Jersey Plant Site

Geologic Unit	Thickness (feet)	Porosity (percent)	Hydraulic Gradient (ft/ft) Horizontal/Vertical Ih	Iv	Hydraulic Conductivity (ft/day) Horizontal/Vertical Kh	Kv	Storage Coefficient	Seepage Velocity (ft/day) Horizontal/Vertical Vh	Vv
Water-Table Aquifer (Cape May FM)	12 to 25 Avg. 18	25	0.0038 to 0.011	-	1.87 to 45.52 Avg. 33.12	-	2.3×10^{-4} to 8.9×10^{-4} Avg. 5.7×10^{-4}	0.03 to 2.02 Avg. 0.98	-
Confining Clay Layer	6 to 23 Avg. 14	40	-	0.28 to 0.6 downward 0.04 upward	8.79×10^{-5}	7.11×10^{-5} to 1.91×10^{-4}		-	4.98×10^{-5} to 1.07×10^{-4} downward 1.91×10^{-5} upward
First Artesian Aquifer	11 to 32 Avg. 21	30	.0045	-	200	-	4.6×10^{-4}	3	-

NLI 001 0041

tivity is about 8.87 x 10^{-5} ft/day (3.10 x 10^{-8} cm/s). The parameters of the first artesian aquifer are based on pumping tests carried out by Geraghty & Miller, Inc., in a similar geologic setting about five miles from the site.

Groundwater Flow Rates

The horizontal groundwater flow rates in the water-table aquifer vary between 0.03 - 2.0 ft/day. The southeastern corner of the site has steeper gradient, resulting in a faster movement of the groundwater. The horizontal velocity values were obtained using a hydraulic conductivity range of 1.87 to 45.52 ft/day, an assumed porosity of 25 percent and a hydraulic gradient range of 0.0038 to 0.011. If an average value of 33.12 ft/day for the hydraulic conductivity is used, the average velocity is about 1 ft/day. The flow directions are to the north, the west, and the east, as indicated in Figure 9.

In the first artesian aquifer, the horizontal groundwater flow rate is about 3 ft/day. This velocity was obtained by using a hydraulic conductivity of 200 ft/day, an assumed porosity of 30 percent, and an average hydraulic gradient of 0.0045.

Groundwater in the confining clay layer has a potential for moving downward into the first artesian aquifer except at Well 11, where the groundwater flow direction was found to be upward. The positive head difference, although small, appears to be anamolous and related to geologic conditions. Further test drilling in this area is recommended to clarify stratigraphic and hydraulic conditions.

The downward seepage velocity in the confining clay layer was found to vary from 1.07×10^{-5} ft/day to 4.97×10^{-5} ft/day. These values are based on a range of vertical hydraulic gradients of 0.28 to 0.6, a vertical hydraulic conductivity of 7.11×10^{-5} ft/day and an assumed clay porosity of 40 percent. The upward seepage velocity in the Well 11 area is about 1.91×10^{-5} ft/day, using a vertical hydraulic gradient of 0.04 and a vertical conductivity of 1.91×10^{-4} ft/day.

GROUNDWATER QUALITY

Introduction

A groundwater quality study was performed in connection with the October 6, 1982 Administrative Consent Order issued by the New Jersey Department of Environmental Protecion. As amended on February 7, 1983, the Consent Order required NL to install two monitoring wells in the 60 to 75 feet water-bearing zone (first artesian aquifer) and to determine the direction, rate of groundwater flow, and water quality in this formation. In addition the Consent Order required NL to submit a design for a ground-water abatement system with the objective of preventing off-site migration of groundwater containing lead in a concentration greater than 0.05 mg/L.

Samples of groundwater were collected and analyzed in the laboratory. The results were mapped to determine the horizontal and vertical extent of groundwater contamination. Using aquifer parameters obtained from the field program and literature, computer simulations were carried out in order to evaluate alternative abatement schemes and to select the most effective abatement system.

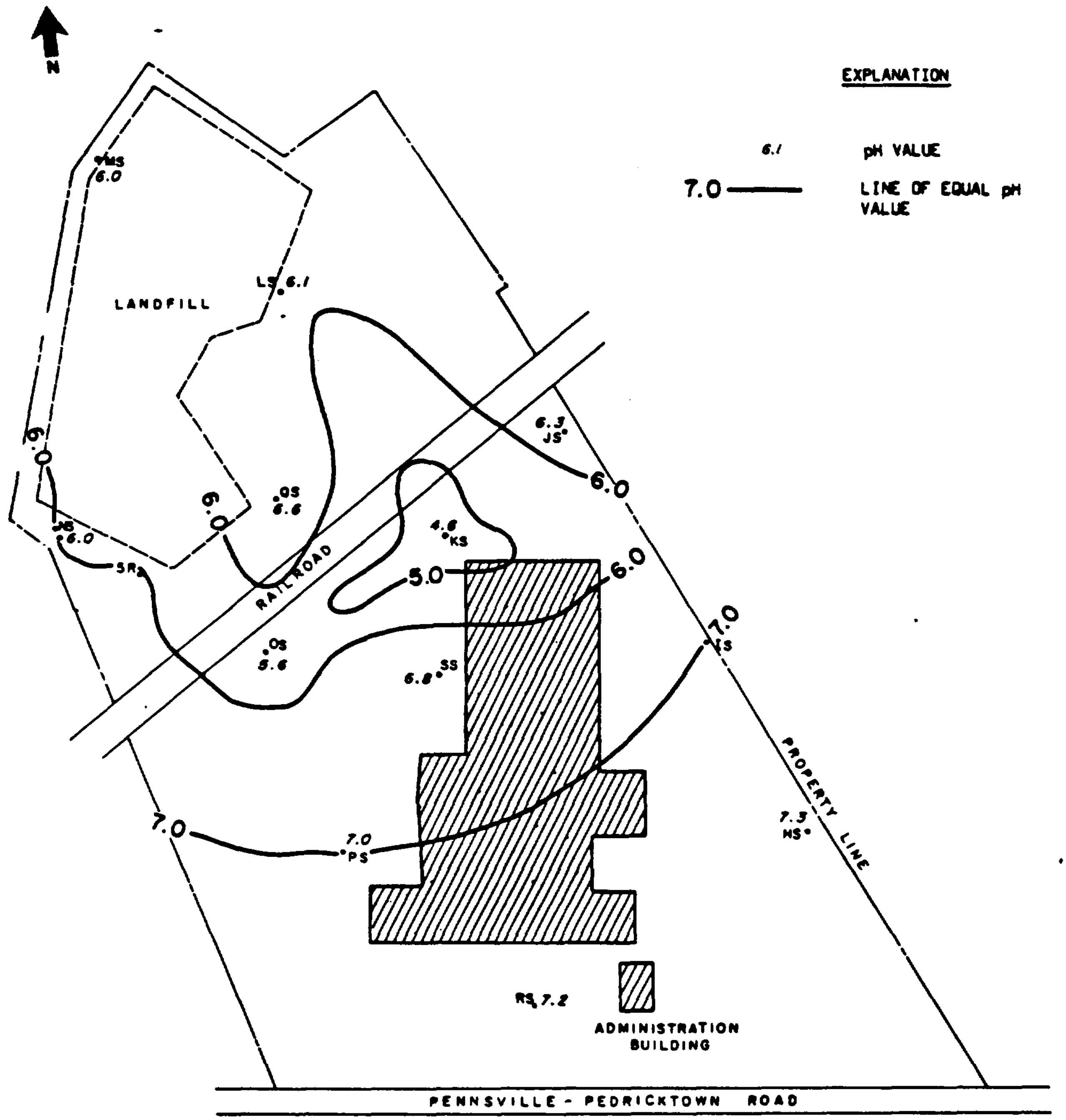
Analysis and Interpretation

The monitoring program was designed to measure the impact of lead-acid battery handling on groundwater quality. Because sulfuric acid and lead are major components of batteries, pH, sulfate, and lead measurements are the most important. Measurements of total dissolved solids and specific conductance provide quality control because of their expected correspondence with sulfate readings. Turbidity measurements were made to possibly aid in the interpretation of the lead data. The quality of the data was also monitored by taking replicates at six wells and comparing the results. All samples were coded with random numbers so the laboratory would not know which samples were replicates.

Results of the quality control samples and indicators show that sampling and analysis was performed in a consistent and satisfactory manner (Tables 6 and 7). Even the lead results for filtered and unfiltered samples are fairly close in most cases even though the turbidity, and hence total solids content of the samples, varied considerably. Different total solids levels could have an important impact on lead concentrations in unfiltered samples, whereas it would be expected to have a minimal impact on filtered samples.

The highest levels of pH, lead, and sulfate measurements occur in the area of well K in the upper part of the water-table aquifer (Figures 16, 17, 18, and 20) and in the area of well S in the deep part of the water-table aquifer (Figures 21, 22, 23, and 24).

Although data from fully penetrating wells are included in these figures, only the data from the partially penetrating wells were used to draw the contours. Considering that the native pH in the area is approximately 7, pH values of 5 and below in the central part of the plant site (Figures 16 and 21) reflect the possible influence of battery acid. Sulfate concentrations are depicted in Figures 20 and 24. Background levels in the area appear to be less than 100 mg/L. The highest values of sulfate (over



0 100 200 300 FEET

SUBJECT

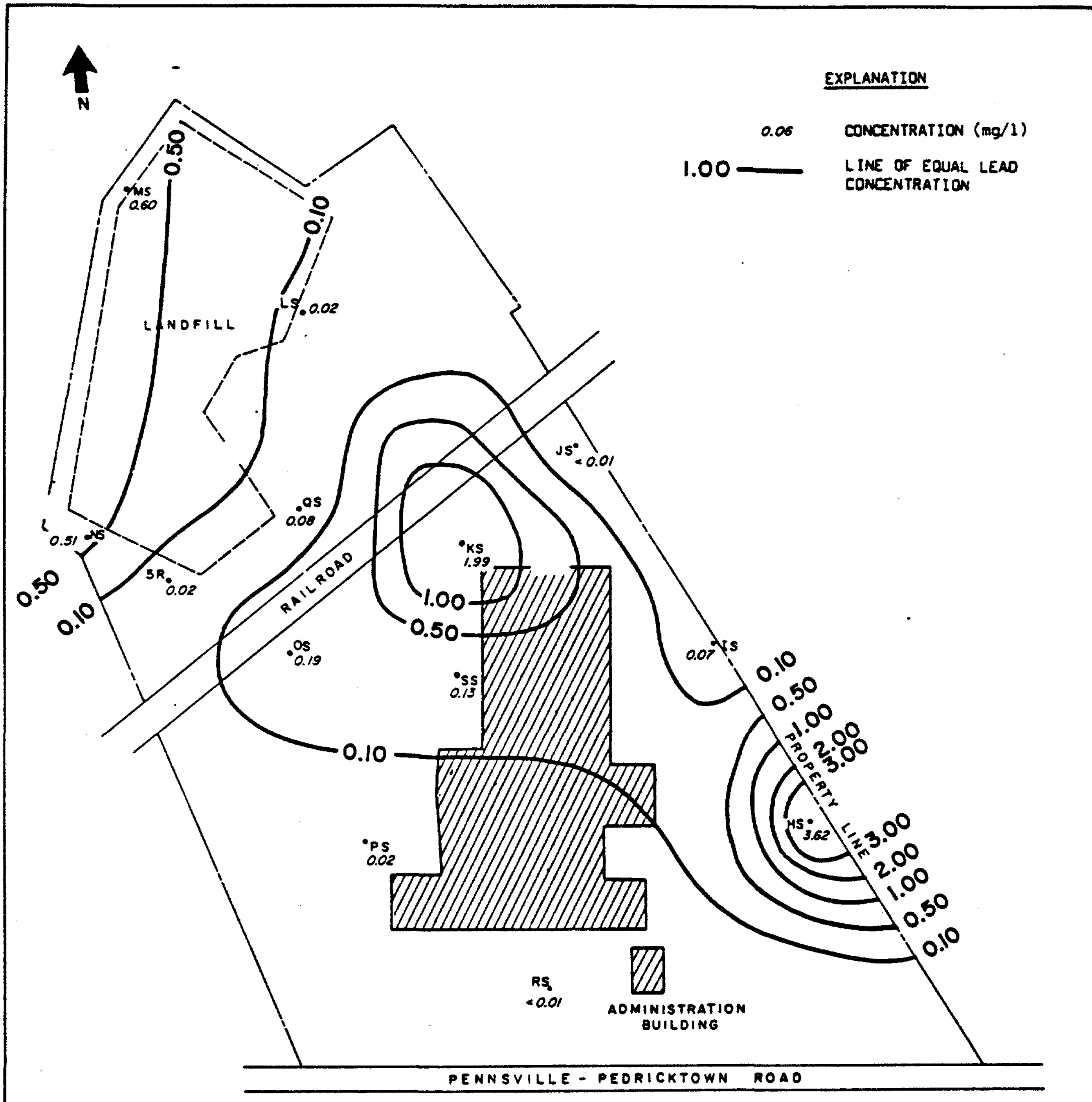
pH IN UPPER WATER TABLE ZONE
JANUARY, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER PREPARED BY CICIO/PADULA/SCHAFFNER PROJECT MGR K. ATOBRAH	SCALE SHOWN DATE 4-83	FIGURE 16

NLI 001 0046



SUBJECT

FILTERED LEAD CONCENTRATION IN UPPER WATER TABLE ZONE JANUARY, 1983

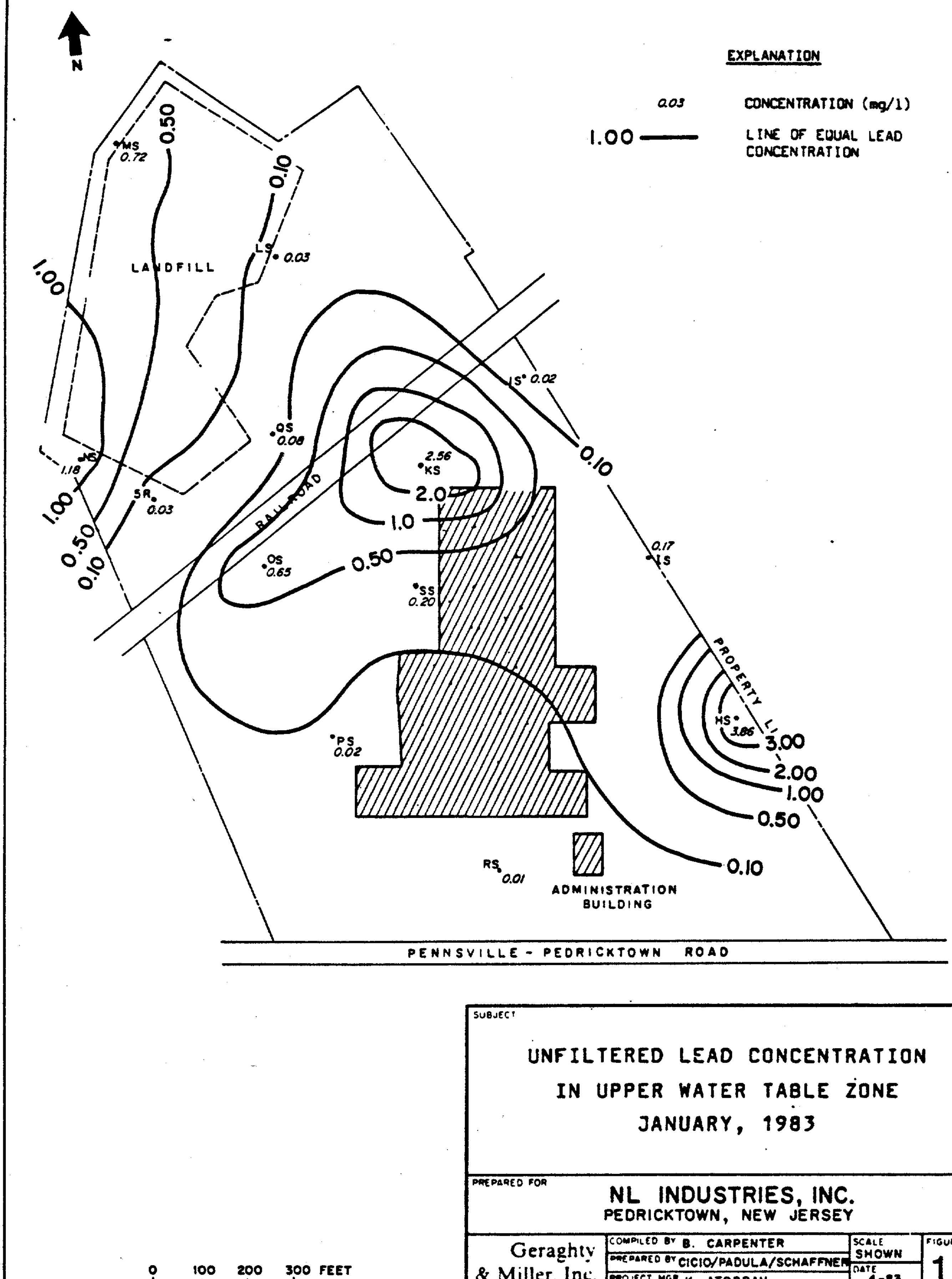
PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

0 100 200 300 FEET

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 17
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		

NLI 001 0047



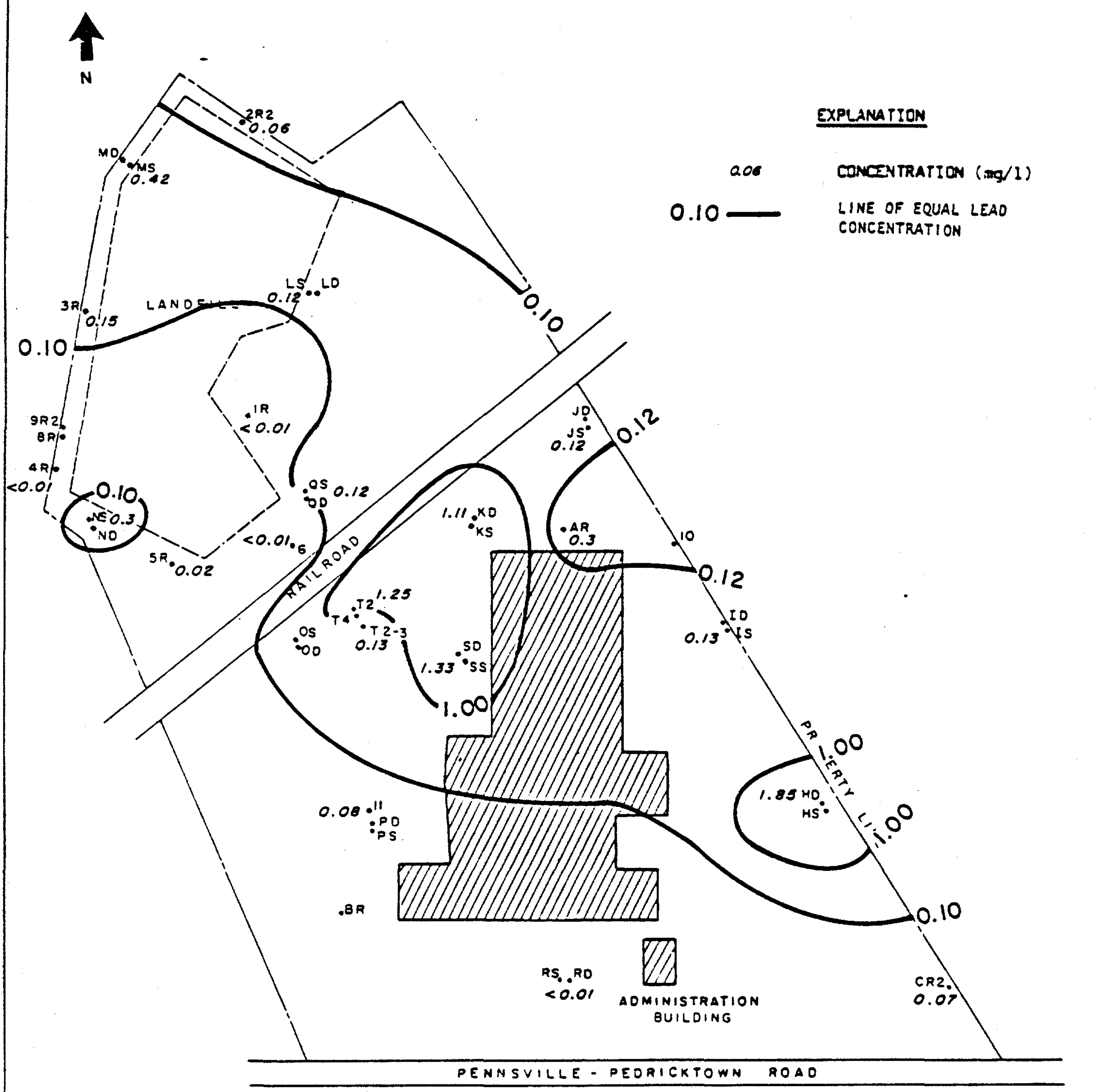
SUBJECT

UNFILTERED LEAD CONCENTRATION
IN UPPER WATER TABLE ZONE
JANUARY, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 18
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		



0 100 200 300 FEET

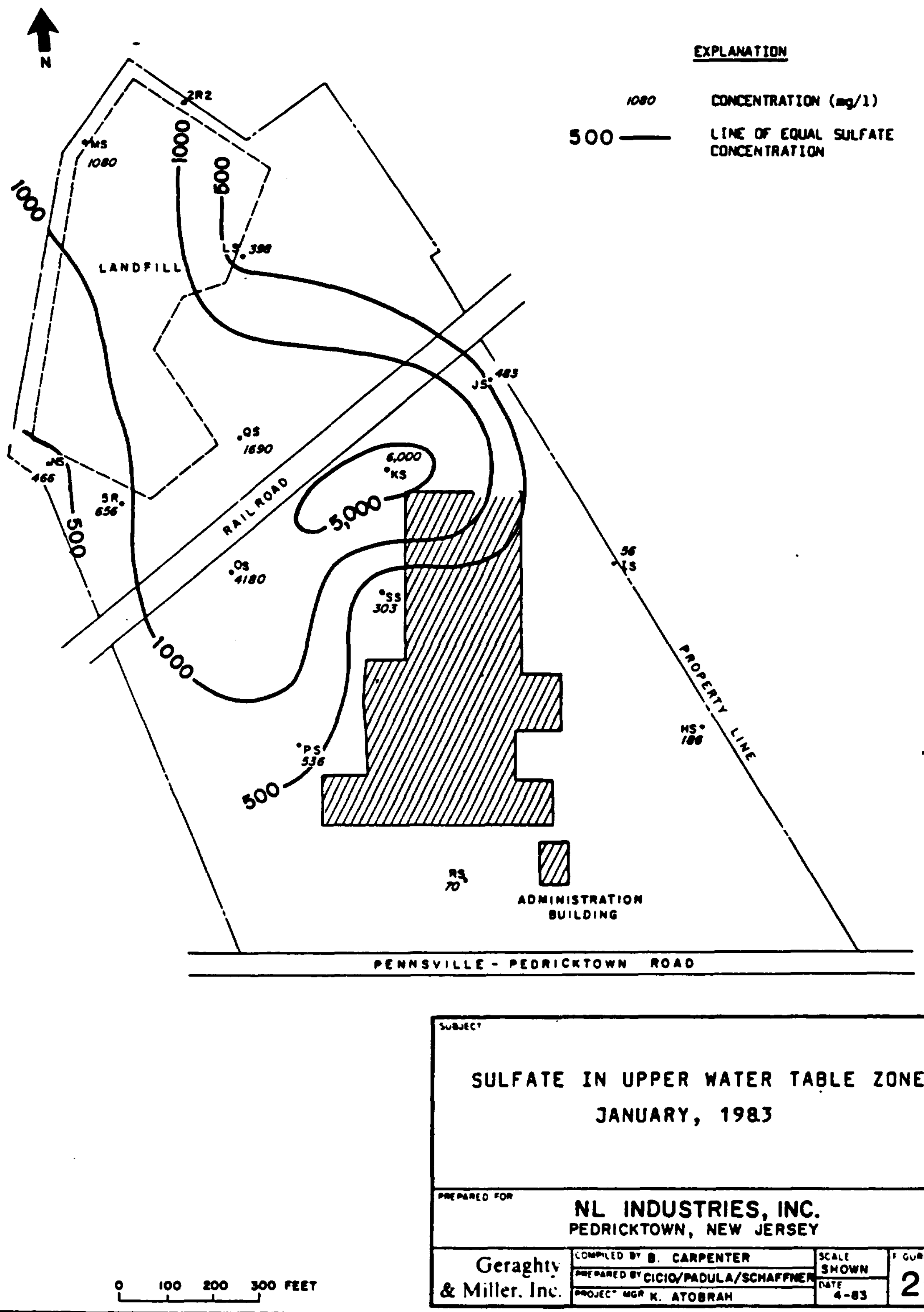
SUBJECT

AVERAGE FILTERED LEAD CONCENTRATION
IN WATER TABLE AQUIFER
JANUARY, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B CARPENTER PREPARED BY CICIO/PADULA/SCHAFFNER PROJECT MGR K. ATOBRAH	SCALE SHOWN DATE 4-83	FIGURE 19



SUBJECT

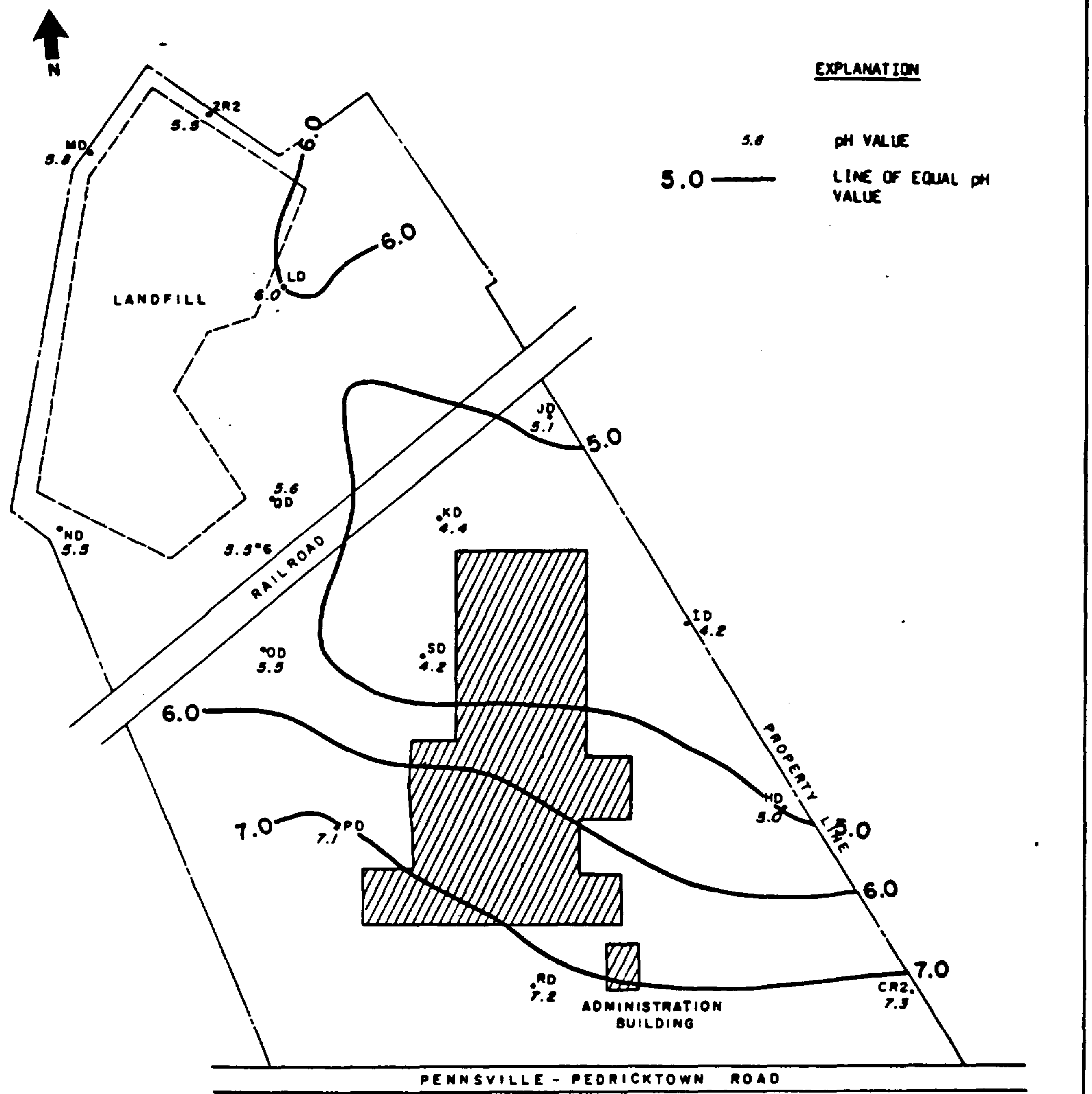
SULFATE IN UPPER WATER TABLE ZONE
JANUARY, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 20
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		

NLI 001 0050



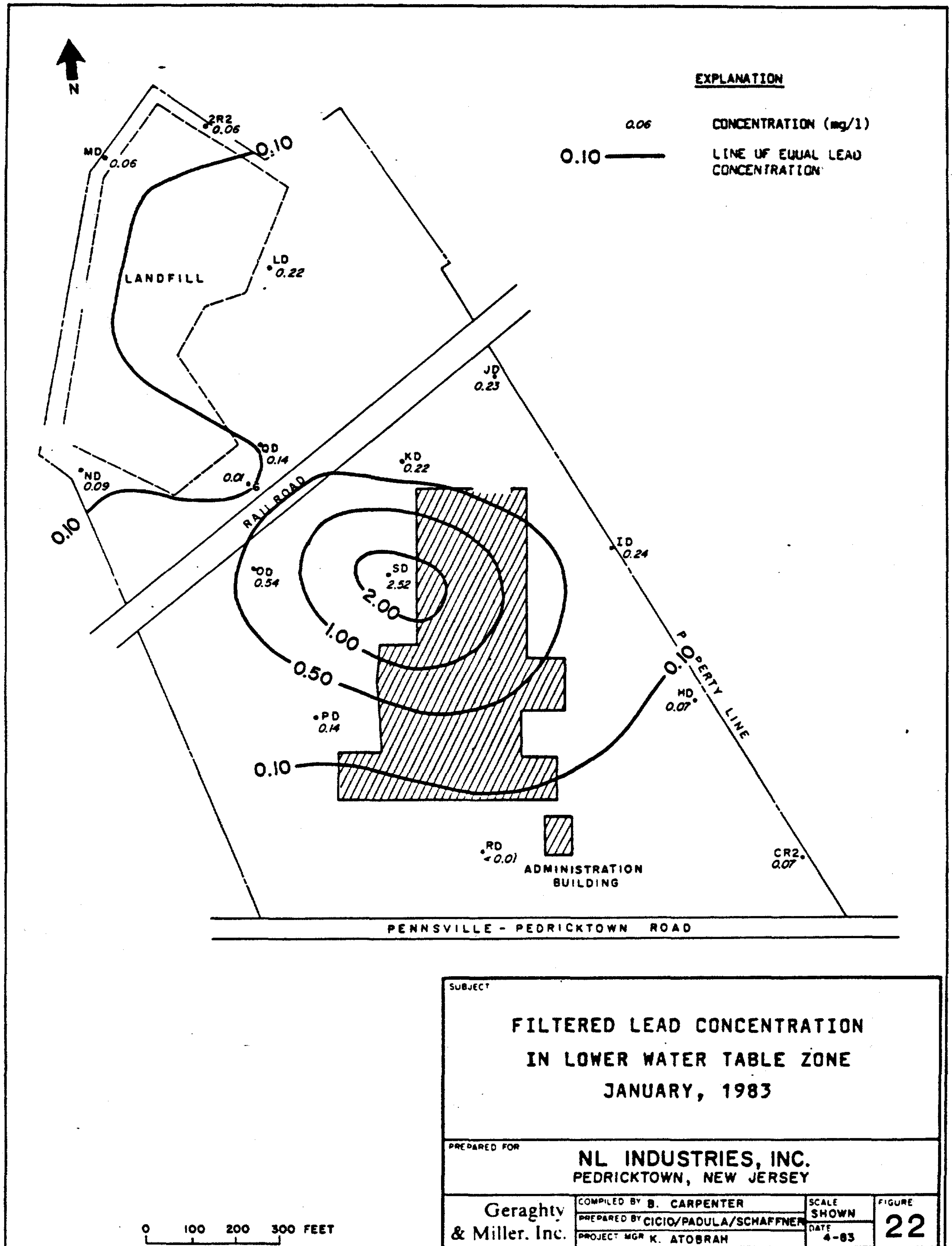
SUBJECT

pH IN LOWER WATER TABLE ZONE
JANUARY, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 21
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		



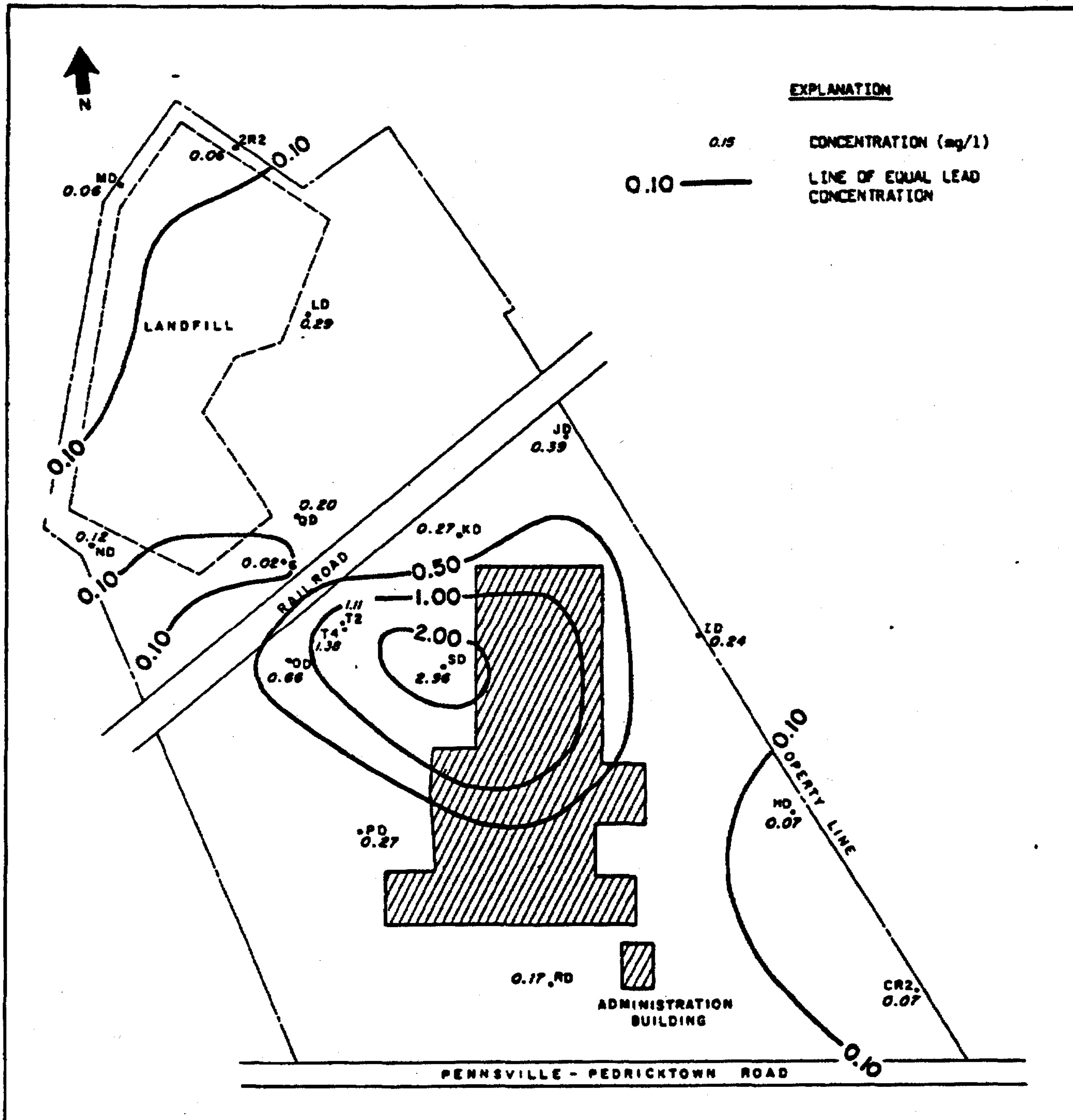
SUBJECT

FILTERED LEAD CONCENTRATION IN LOWER WATER TABLE ZONE JANUARY, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 22
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		



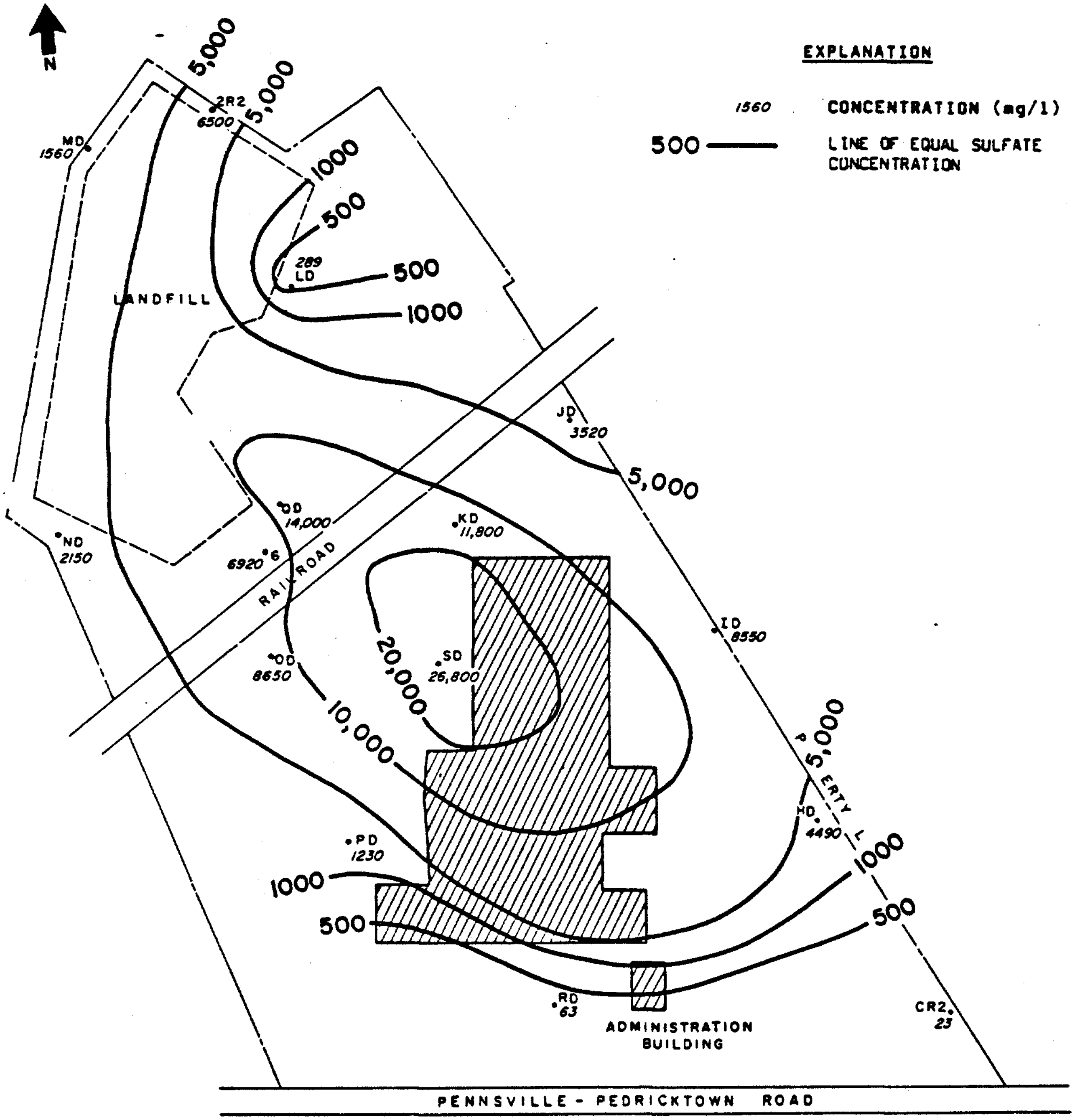
SUBJECT

UNFILTERED LEAD CONCENTRATION IN LOWER WATER TABLE ZONE JANUARY, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER PREPARED BY CICIO/PADULA/SCHAFFNER PROJECT MGR K. ATOBRAH	SCALE SHOWN DATE 4-83	FIGURE 23



SUBJECT

SULFATE IN LOWER WATER TABLE ZONE
JANUARY, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 24
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		

NLI 001 0054

Table 6. Field Test Results for Well Sampling Program, January 1983, NL Industries, Pedricktown, New Jersey

Date	Well	Random Number	pH	Turbidity (NTU)	Specific Conductance umhos/cm	Temperature Degrees C	Pumping Rate (gallons per minute)
2-Inch Diameter Wells							
1/ 6/83	HD	242	3.36	24	8,000	13.5	.21
1/ 6/83	HS	630	5.41	79	540	12	.09
1/ 6/83	ID	261	2.38	19	>8,000	13	.29
1/ 6/83	IS	985	3.35	31	180	11	.14
1/ 6/83	IS*	638	3.29	30	210	11	.14
1/ 6/83	JD	665	3.30	46	6,000	14	.21
1/ 6/83	JS	856	4.52	245	1,100	12.5	.20
1/ 5/83	KD	504	2.55	300	>8,000	--	--
1/ 5/83	KS	406	2.59	17	>8,000	--	--
1/ 6/83	LD	522	4.42	45	700	12	.27
1/ 6/83	LS	415	4.55	17	1,025	9	.21
1/ 6/83	MD	254	4.24	20	3,500	14	.28
1/ 6/83	MS	412	4.51	58	2,300	12.5	.25
1/ 6/83	MS*	417	5.02	42	2,300	12.5	.25
1/ 6/83	ND	984	3.68	42	4,500	14.5	.23
1/ 6/83	NS	226	4.04	400	1,050	12	.12
1/ 5/83	OD	131	3.73	22	>8,000	--	<.20
1/ 5/83	OS	545	4.19	120	8,000	12	.22
1/ 5/83	PD	140	5.67	7.8	3,000	13	.25
1/ 5/83	PS	988	4.99	4.5	1,250	12	.27
1/ 6/83	QD	557	4.61	59	<50	13	.23
1/ 6/83	QD*	287	4.62	54	<50	13	.23
1/ 6/83	QS	372	5.41	40	4,000	12	.25
1/ 5/83	RD	890	5.44	240	450	--	.29
1/ 5/83	RS	584	5.75	25	290	12	.25
1/ 5/83	RS*	785	5.86	28	300	12	.25
1/ 5/83	SD	246	2.15	180	>8,000	13	<.20
1/ 5/83	SS	349	5.15	165	950	10	.16
1/ 6/83	T2	978	3.93	70	>8,000	10	.26

*Replicate samples

Table 6. Continued.

Date	Well	Random Number	pH	Turbidity (NTU)	Specific Conductance umhos/cm	Temperature Degrees C	Pumping Rate (gallons per minute)
4-Inch Diameter Wells							
1/12/83	T4	567	4.53	43	>8,000	15	1
1/12/83	1R	892	4.61	51	>8,000	16.5	1
1/12/83	2R2	102	6.98	34	>8,000	17	1
1/12/83	3R	626	3.66	44	3,400	17	1
1/12/83	4R	787	4.57	2.8	2,400	--	1
1/11/83	5R	473	4.45	25	1,500	14	1
1/11/83	6	512	4.50	25	>8,000	15	1
1/11/83	8R	230	5.85	4.3	65	14	1
1/11/83	8R*	139	5.89	4.5	65	14	1
1/11/83	9R2	441	5.57	4.6	<50	15	1
1/13/83	10	965	5.41	3.2	140	15	1
1/12/83	11*	599	4.75	13	>8,000	15	1
1/12/83	11	186	4.79	15	>8,000	15	1
1/12/83	AR	918	2.16	15	>8,000	14	1
1/11/83	BR	903	5.42	3	>8,000	15	1
1/12/83	CR2	940	5.97	17	140	15.5	1

*Replicate sample

Table 7. Laboratory Results for Well Sampling Program, January 1983, NL Industries, Pedricktown, New Jersey.

Well No.	Random No.	Dissolved Solids (mg/l)	pH	Sulfate (mg/l)	Turbidity (NTU)	Unfiltered Lead (mg/l)	Filtered Lead (mg/l)
HS	630	373	7.3	186	70	3.86	3.62
HD	242	5,600	5.0	4,490	3.8	0.07	0.07
IS	985	272	6.9	58	73	0.17	0.06
IS*	638	267	7.0	53	30	0.16	0.08
ID	261	11,300	4.2	8,550	16	0.24	0.24
JS	856	855	6.3	483	250	0.02	<0.01
JD	665	5,320	5.1	3,520	34	0.39	0.23
KS	406	8,250	4.6	6,000	>1,000	2.56	1.99
KD	504	15,800	4.4	11,000	180	0.27	0.22
LS	415	644	6.1	398	1.4	0.03	0.02
LD	522	428	6.0	289	30	0.29	0.22
MS	412	1,730	6.0	1,080	62	0.74	0.58
MS*	417	1,690	6.0	1,080	32	0.70	0.62
MD	254	2,510	5.8	1,560	5.5	0.06	0.06
NS	226	713	6.0	466	550	1.18	0.51
ND	984	3,090	5.5	2,150	33	0.12	0.09
OS	545	5,870	5.6	4,140	95	0.65	0.19
OD	131	10,500	5.5	8,650	20	0.66	0.54
PS	988	910	7.0	536	6.8	0.02	0.02
PD	140	1,880	7.1	1,230	5	0.27	0.14
QS	372	2,450	6.6	1,690	62	0.08	0.08
QD	557	20,700	5.6	14,500	85	0.20	0.14
QD*	287	19,700	5.6	13,500	150	0.19	0.13
RS	584	202	7.2	70	22	0.01	<0.01
RS*	785	180	7.1	67	30	0.01	<0.01
RD	890	215	7.2	63	>1,000	0.17	<0.01
SS	349	485	6.8	303	150	0.20	0.13
SD	246	35,100	4.2	26,800	125	2.96	2.52
T2	978	11,200	5.2	8,150	66	1.38	1.25
T4	567	10,700	5.6	8,650	70	1.11	0.13
1R	892	10,700	5.5	8,850	83	0.28	<0.01
2R2	102	11,200	6.8	6,500	95	0.06	0.06
3R	626	2,730	5.4	1,580	25	0.15	0.15
4R	787	1,380	5.8	560	1.0	<0.01	<0.01
5R	473	1,120	6.1	656	15	0.03	0.02

* Replicate Sample

Table 7. (Continued)

Well No.	Random No.	Dissolved Solids (mg/l)	pH	Sulfate (mg/l)	Turbidity (NTU)	Unfiltered Lead (mg/l)	Filtered Lead (mg/l)
6	512	7,380	5.5	6,920	30	0.02	<0.01
8R	230	58	7.5	3	3.8	<0.01	<0.01
8R*	139	83	7.6	4	3.5	0.02	<0.01
9R2	441	51	7.5	3	4.5	0.01	<0.01
10	965	146	7.6	26	1.8	<0.01	<0.01
11	186	22,100	5.7	14,700	6.5	0.46	0.40
11*	599	20,200	5.6	14,800	5.8	0.40	0.36
AR	918	10,300	4.0	7,250	2.1	0.30	0.30
BR	903	14,700	5.8	11,400	3.8	0.25	0.25
CR2	940	190	7.3	23	125	0.07	0.07

* Replicate Sample

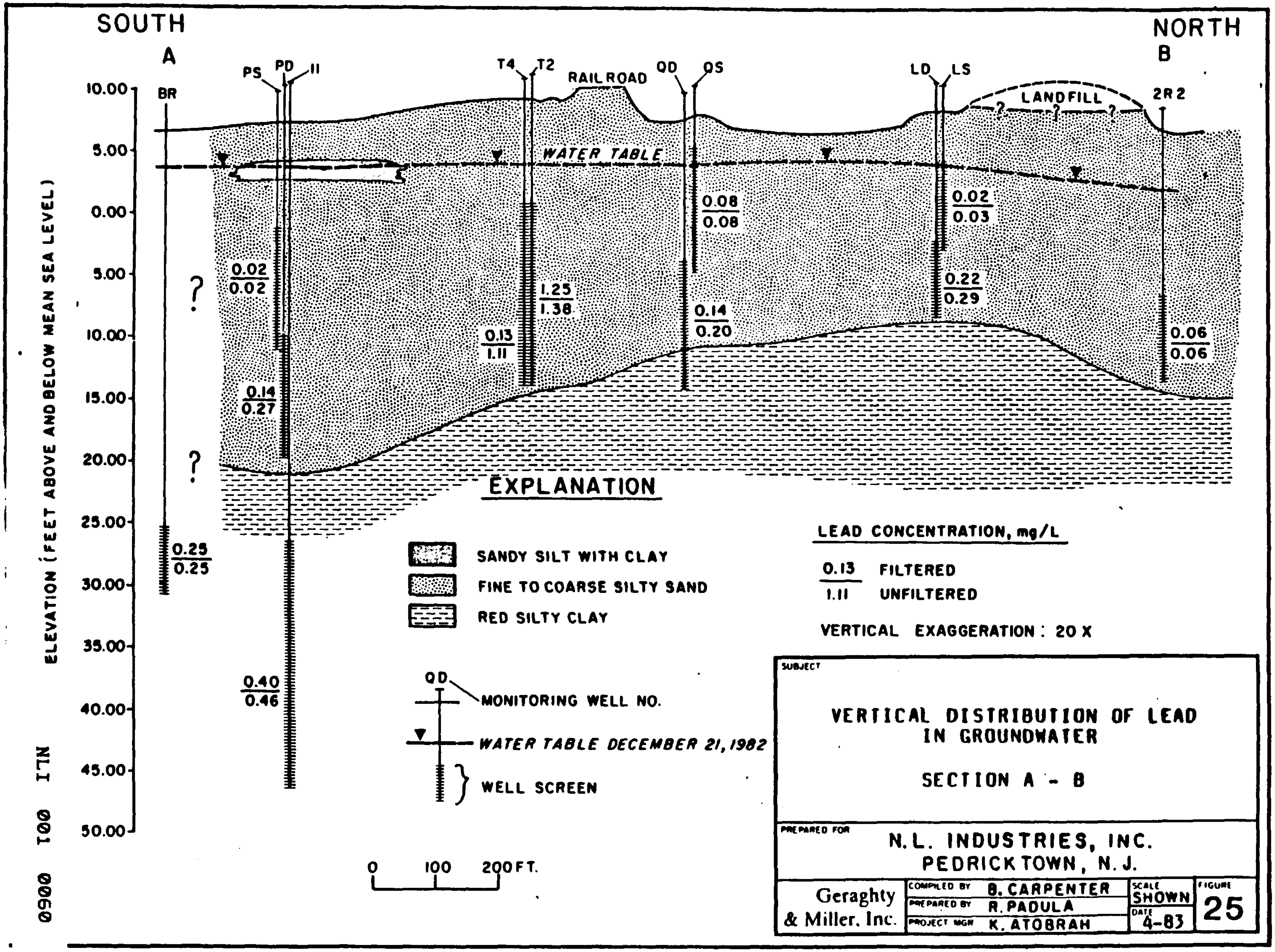
Analyses were performed by Century Environmental Testing Labs., Inc., Thorofare, New Jersey.

10,000 mg/L) are found in the lower part of the water-table aquifer (Figure 24). This type of stratification indicates that recent recharge is relatively clean compared to that in earlier times. The same observation holds for pH in the area of well cluster S: the pH in the shallow water-table zone is more normal than the pH in the deep water-table zone.

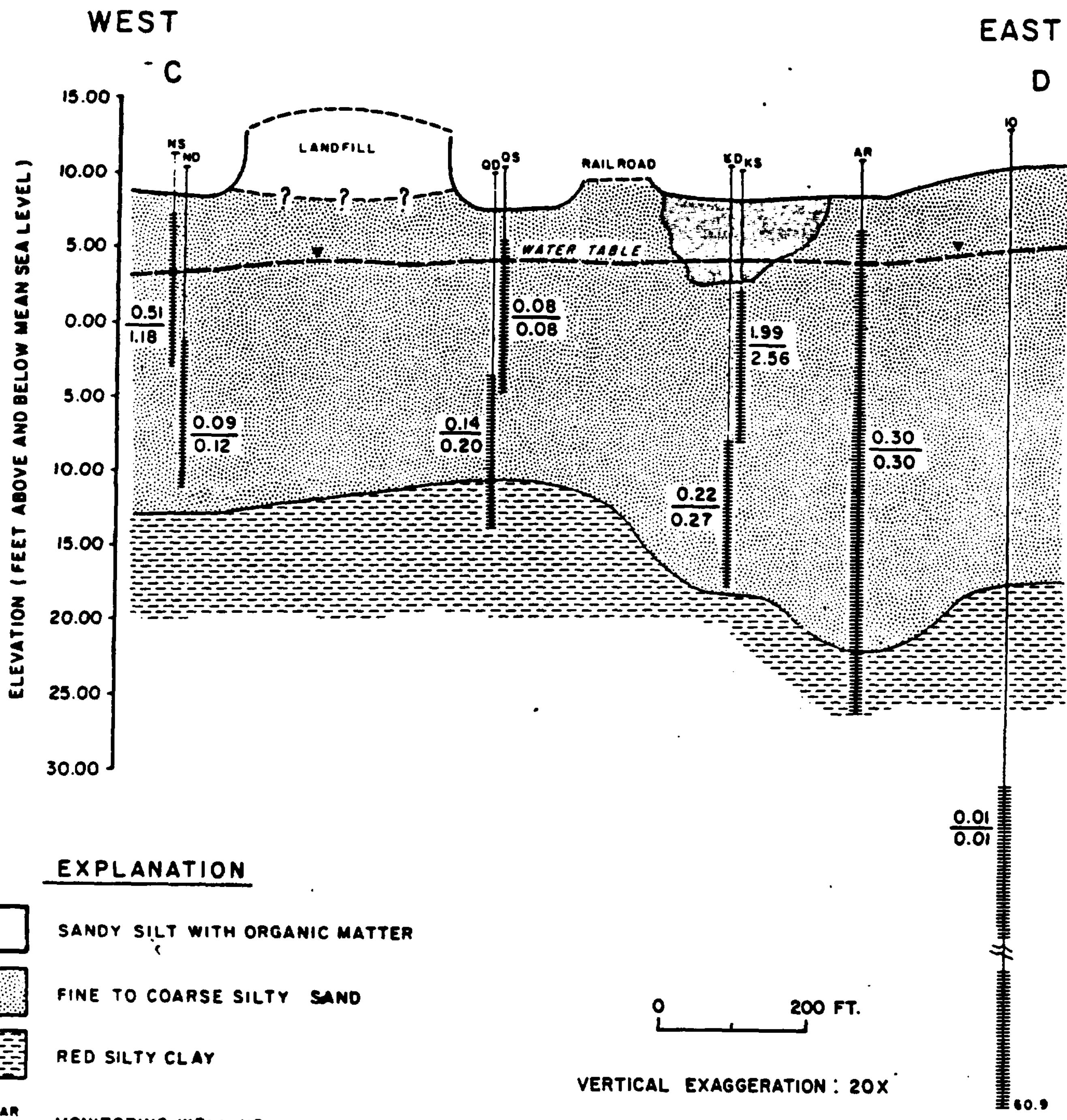
Lead concentrations range up to approximately 3 mg/L in the central region of the plant site and in well HS (Figures 17, 18, 22, and 23). In several water-table wells, the lead concentration is below the drinking-water standard of 0.05 mg/L. Different materials handling practices through time and variations in recharge probably contribute to differences in lead concentrations in water from wells within a cluster. The vertical distribution of lead in groundwater is depicted in Figures 25 and 26. In general, lead concentrations in the newly installed observations wells are higher than those observed in the previously installed monitoring wells which are screened along the entire water table aquifer.

Figure 19 shows average filtered lead concentrations in the entire water-table aquifer. These values were derived by averaging lead concentrations observed in both the upper and lower screen zones and combining these with lead levels observed in the fully screened monitoring wells. Some resampling of selected wells is advisable to recheck observed lead concentrations, especially in the wells near the landfill, Wells 11 and BR, and Cluster H.

The most important variable that influences lead mobility in soils is the pH. If acid and lead are deposited together, lead will move fairly well through the soil. If clean recharge follows and the pH rises, lead


SOUTH
A
NORTH
B
BR
PS
PD
11
T4
T2
RAILROAD
QD
QS
LD
LS
LANDFILL
2R2
WATER TABLE
ELEVATION (FEET ABOVE AND BELOW MEAN SEA LEVEL)
10.00
5.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
0.02 / 0.02
0.14 / 0.27
0.40 / 0.46
0.25 / 0.25
0.13 / 1.11
1.25 / 1.38
0.08 / 0.08
0.14 / 0.20
0.02 / 0.03
0.22 / 0.29
0.06 / 0.06
EXPLANATION
SANDY SILT WITH CLAY
FINE TO COARSE SILTY SAND
RED SILTY CLAY
LEAD CONCENTRATION, mg/L
0.13 FILTERED
1.11 UNFILTERED
VERTICAL EXAGGERATION : 20 X
QD
MONITORING WELL NO.
WATER TABLE DECEMBER 21, 1982
WELL SCREEN
0
100
200 FT.
SUBJECT
VERTICAL DISTRIBUTION OF LEAD IN GROUNDWATER
SECTION A - B
PREPARED FOR
N.L. INDUSTRIES, INC.
PEDRICKTOWN, N.J.
Geraghty & Miller, Inc.
COMPILED BY B. CARPENTER
PREPARED BY R. PADULA
PROJECT MGR K. ATOBRAH
SCALE SHOWN
DATE 4-83
FIGURE 25

NLI 001 0900



EXPLANATION

SANDY SILT WITH ORGANIC MATTER

FINE TO COARSE SILTY SAND

RED SILTY CLAY

AR — MONITORING WELL NO.

WATER TABLE DECEMBER 21, 1982

WELL SCREEN

LEAD CONCENTRATION, mg/L

0.14 FILTERED
0.20 UNFILTERED

SUBJECT

VERTICAL DISTRIBUTION OF LEAD
IN GROUNDWATER

SECTION C - D

PREPARED FOR

N.L. INDUSTRIES, INC.
PEDRICKTOWN, N.J.

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 26
	PREPARED BY R. PADULA		
	PROJECT MGR K. ATOBRAH	DATE 4-83	

becomes less soluble and less mobile. Although elevated concentrations of lead are evident in large parts of the plant site, it is reasonable to expect that the mobility of the lead and its tendency to move offsite will decline as water flows away from the relatively acidic central area.

GROUNDWATER ABATEMENT SYSTEM

The objective of the abatement system is to prevent the off-site migration of contaminated groundwater containing greater than 0.05 mg/L lead across the property lines of the facility.

The impact of the various abatement options on the groundwater system at the site has been studied using a numerical finite-difference model modified from Prickett and Lonnquist (1971). The modifications of the basic aquifer simulation program include water-table conditions and leaky artesian conditions. A description of this model is contained in Appendix E.

Design Criteria

From the results of literature revew and the field work, including the pumping test conducted at the site, the following characteristics are obtained for the water-table aquifer:

a. the yield per well is relatively low, about 7 gallons per minute (gpm).

b. the seasonal water-level fluctuation is about 2.5 feet.

c. the water table is about 6 feet below ground surface.

d. the drawdown in a pumping well is more than half the total saturated thickness of the aquifer.

e. the highest level of lead in ground water below the central area of the plant is approximately 3 mg/L. If water of this concentration were to be continuously pumped from a remedial wells, it would have to be mixed with 30 times the volume of clean water (no detectable lead) if the lead concentration in a stream effluent is to be less than 0.10 mg/L.

Based on these observations, the important criteria for the abatement system are:

1. the hydraulic heads at the property lines should be lower than the natural conditions to reverse flow.

2. the spacing between discharge points (wells, etc.) should create a significant drop of head at the mid-point in order to reverse flow and create a hydraulic barrier.

3. The equivalent volume of water pumped at the center of the plume with the maximum concentration of lead has to be diluted 30 times.

Selection of Abatement System

In general the best remedial options for containment of contaminated groundwater are by (1) fluid isolation, involving encapsulation of plume fluids using slurry walls and/or surface seal; and (2) fluid removal, involving recovery of plume fluids using wells, drains, trenches, and/or treatment of fluids. Considerations of construction and reliability lead us to discuss three options: the installation of slurry walls along the perimeter of the facility, the utilization of collector trenches with common suction points, and the use of wellpoints connected to common headers.

Fluid Isolation

The slurry wall system involves surrounding the plume with walls of low permeability material which are anchored into the confining clay layer. The land surface is then modified to reduce recharge.

The depth of the slurry wall at the site is estimated at 25 feet. The total length of wall around the property lines is about 6,000 feet. Either the trencher method or the vibrating beam method can be employed for the wall installation. Wall thickness using the trencher method is a minimum of one foot. The vibrating beam creates a wall with a thickness of about one-half foot. Both bentonite and/or asphalt slurries are used for the walls.

The overall cost of the slurry-wall system not including water treatment is over $3.0 million, which is broken down as follows:

	Estimated Cost
Wall materials and installation ($10.00 per vertical square foot)	$ 1,500,000
Land surface treatment, including recontouring, grading and vegetation. ($0.75 per square foot)	1,300,000
Installation of pumping wells and recovery system to prevent mounding of groundwater after installation of slurry walls	500,000
Total:	$ 3,300,000

Apart from the cost, slurry wall longevity is unknown, the regulatory implications of leakage are unclear, and wall system maintenance is technically infeasible. In addition, the full control of surface recharge is difficult to achieve, so that a permanent pumping system has to be in place to prevent groundwater mounding at the site.

Practical considerations, in addition to cost, remove the slurry wall system from serious consideration as an abatement system.

Fluid Removal

The goal of this abatement system is to control plume movement by pumping. This can be accomplished by installation of collector trenches or by well points.

Collector Trench

The system involves the construction of trenches which would be pumped on a continuous basis to capture and remove contaminated groundwater. The trenches are deepened near their midpoints, and collector sumps are installed (usually a large-diameter, perforated cylinder). A pump and an automatic water-level recorder are installed in each sump to control and monitor the groundwater heads.

The presence of fine-to-coarse sand in the water-table aquifer at the site will require shoring to prevent the trench walls from caving. In addition, dewatering may be necessary during construction. Since the groundwater flow at the site is in several directions, installation of trenches will be required along the eastern, the western, and the northern edges of the facility.

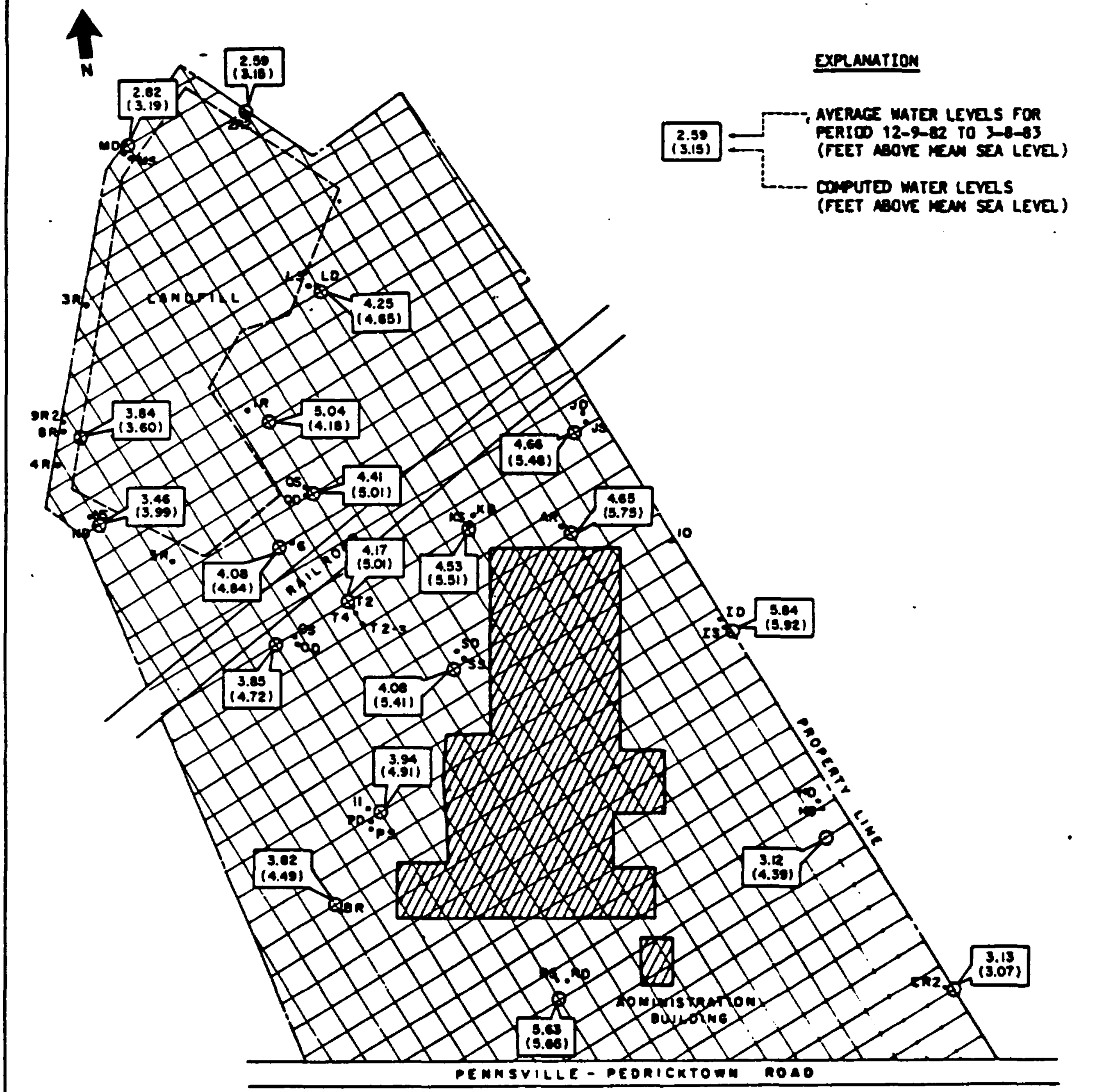
The total trenching volume required at the site is about 1.53 million cubic feet. The estimated cost of trench construction based on Geraghty & Miller, Inc.'s experience in similar material elsewhere in New Jersey is $0.40 per cubic foot. Therefore, the estimated cost of trench installation is about $600,000 plus possible cost of treatment of water pumped during the dewatering procedures.

Although less costly than the slurry-wall methods, a trench system at this site may have technical deficiencies. At times of low water levels, the system may not function efficiently. Also, construction problems may arise during excavation due to the engineering properties of the soil and aquifer. Therefore, a collector trench system is not recommended.

Wellpoint System

The groundwater abatement system using wellpoints is considered a more favorable option in view of variable groundwater gradients at the site, the potential movement of the plume in different directions, and the depth to the water-table.

To design the wellpoint system, taking into account all the necessary criteria, the observed average water levels in the field for the period September 1982 to March 1983 were first duplicated by the model (see Figure 27). The comparison of the values obtained indicates that the simulated groundwater elevations approximate the field values quite closely with a correlation coefficient of.90. Therefore, in modeling, the computed values were used for initial water-level conditions prior to simulating the impact caused by the number and spacing of the wellpoints.



SUBJECT

CALIBRATION OF FLOW MODEL:

AVERAGE FIELD HEADS VS COMPUTED HEADS IN WATER-TABLE AQUIFER

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

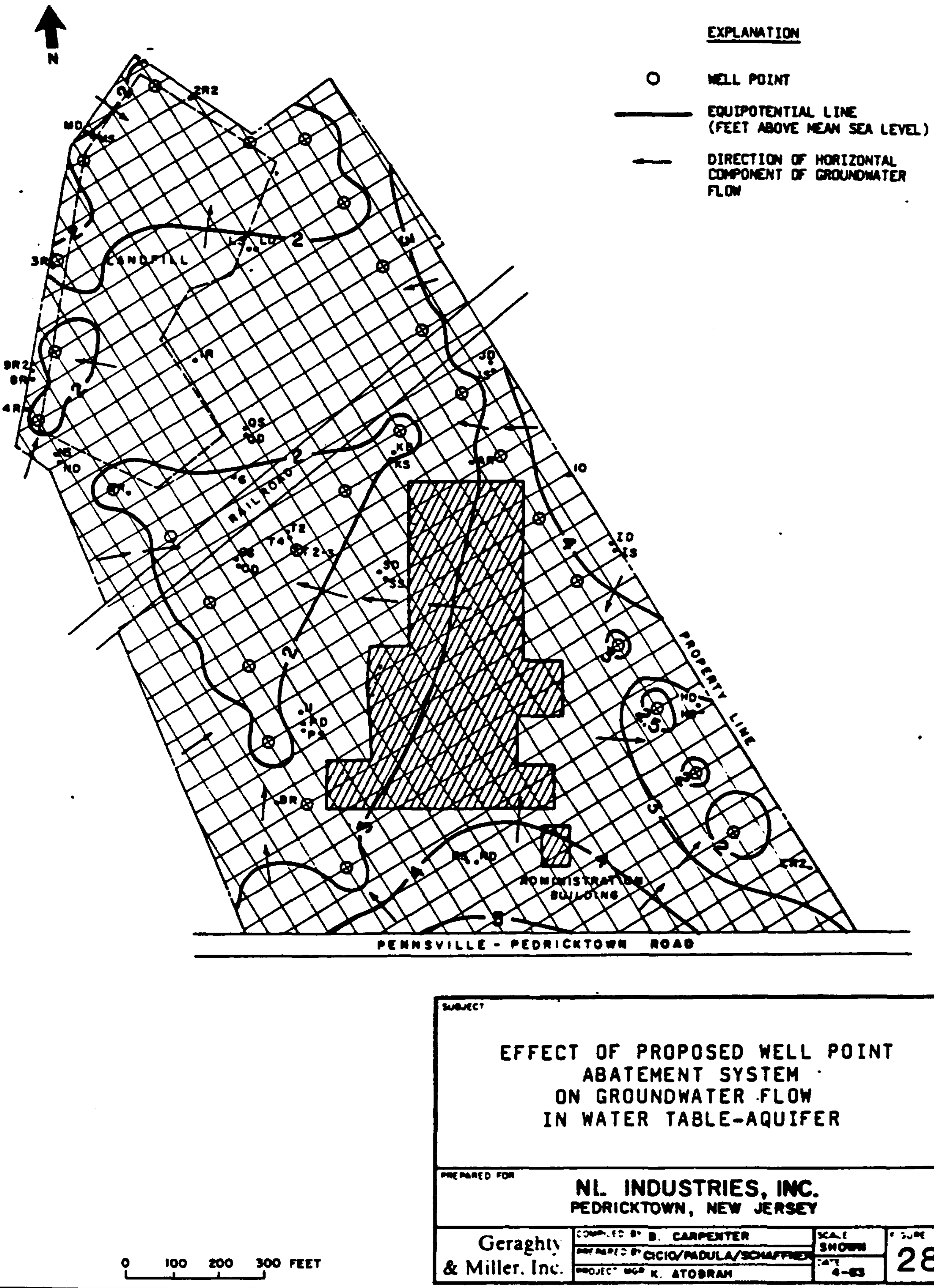
Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 27
	PREPARED BY CICIO/PAOLULA/SCHAFFNER	DATE 4-83	
	PROJECT MGR K. ATOBRAH		

The total number of wellpoints utilized for modeling of the abatement system is 28, distributed as follows: 12 wellpoints located along the eastern edge, eight wellpoints located along the western edge, five wellpoints located around the landfill at the northern edge of the property, and three wellpoints located across the middle portion of the site. Two of the wellpoints at the middle portion are located in the area of maximum lead concentration. The wellpoints would be screened in the lower portion of the water-table aquifer in order to capture contaminants at any depth within this zone

The output from the model indicates that all the contaminated groundwater is prevented from leaving the property lines (see Figure 28). The minimum head of two feet is found in the middle and the northern portions of the site, and the maximum head of five feet occurs at the southern end of the site.

Each wellpoint is pumped at 5 gpm, giving a total pumpage of 135 gpm or 194,400 gallons per day. The simulation of heads due to pumping the wellpoints is for one year, by which time, steady-state conditions have been reached.

The volume of groundwater in the central zone of the plant, where lead concentrations are highest, is roughly estimated at 8 million gallons. This estimate is based on an area measuring 500 by 500 feet, a saturated thickness of 18 feet, and a porosity of 0.25. Assuming that ten wellpoints are placed in this area with a combined pumping rate of 50 gpm, it would take approximately half a year to remove this contaminated water.



SUBJECT

EFFECT OF PROPOSED WELL POINT ABATEMENT SYSTEM ON GROUNDWATER FLOW IN WATER TABLE-AQUIFER

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE
	PREPARED BY CICIO/PADULA/SCHAFFNER	DATE 4-83	28
	PROJECT MGR K. ATOBRAH		

Because only short pumping tests have been carried out at the site, no information is available on trends of lead concentration with continuous pumping. For this reason, the amount of lead-free water needed for dilution and treatment cannot be calculated.

In order to design an appropriate dilution/treatment system, pilot pumping tests will have to be conducted. During these tests, alternate sections of the wellpoint system would be activated and water samples would be collected for analysis. Based on the results of these pilot tests, the most effective treatment system would be selected.

It is possible to obtain groundwater from the deeper sands of the Magothy-Raritan aquifer. However, this aquifer is already tapped by nearby industries, and a permit for withdrawal would have to be obtained from the NJDEP. The impact of such a diversion on nearby users, as well as the resource itself would have to be carefully evaluated.

Details of the proposed wellpoint abatement system are given below. Some of the already existing wells at the site will be tied in to the wellpoint system, subject to field conditions and engineering considerations. However, most of the monitoring and observation wells will be utilized for monitoring water-level and water quality trends.

The cost of the abatement system consisting of 28 wellpoints, valves, and pumps, is estimated at $150,000 to $200,000.

DETAILS OF PROPOSED WELLPOINT SYSTEM

The wellpoint system consists of a number of wellpoints embedded into a sand stratum below the water table. These wellpoints are connected to a common header line, which is hooked up to a centrifugal pump. As the system is pumped, cones of depression develop around the wellpoints. When the wellpoints are arranged in a line, the cones of depression overlap and a longitudinal hydraulic trench is created. The components of a wellpoint system consists of the wellpoint itself, a riser pipe, a swing joint, and a pump and discharge pipe. It is possible that the actual wellpoint system installed at the site will differ somewhat as construction needs to be adjusted to field conditions and contractor preferences.

Wellpoint

The wellpoint is a self-jetting wellpoint. The wellpoint and riser pipe are connected together and jetted into the ground. While jetting the wellpoint into the ground, the jetting water is forced under pressure (either from a high-pressure hydrant or a jetting pump) down through the riser pipe and wellpoint. The jetting water creates a hole in the soil into which the wellpoint sinks. As the finer soil particles are forced out of the hole, the heavier and coarser particles settle to the bottom of the hole forming a relatively coarse permeable filter around the well screen. The wellpoint is usually set about two feet away from the well header.

Riser Pipe

The riser pipe is pvc pipe threaded at each end. The riser pipe connects the wellpoint to the swing joint which connects into the header pipe.

Swing Joint

The swing joint is used to make the connection between the riser pipe and the header pipe. It is composed of a riser half and a header half. The riser half is attached to the top of the wellpoint riser pipe, the header half is attached to the header pipe. The two halves are joined together after the wellpoint is in place by either a union joint or a rubber suction hose. Each swing joint is equipped with a shut-off valve to permit regulation or complete shutdown of the flow from each well point.

Header Pipe

The header pipe consists of plain-end light weight pvc or steel pipe with swing joints inlets. Sections of the header pipe are coupled together to form a suction line or manifold which conveys the ground water from a series of wellpoints to the suction of the pump. The header pipe is usually in sizes of 6, 8, and 10-inch diameter pipe and in standard lengths of 20 feet. The inlets, to which the swing joints are connected are attached at standard intervals along each length of header pipe. For 6-inch diameter pipe, the inlets are spaced three feet apart with seven inlets per length of header pipe. For 8-inch and larger diameter pipe, the inlets are spaced two feet apart, 10 inlets per length of header pipe.

Wellpoint Pump

The wellpoint pump is basically a centrifugal pump capable of handling large volumes of water. It is also constructed in such a way that muddy or gritty water can be handled without damage to the pump.

Discharge Pipe

The discharge pipe is used to carry the groundwater from the wellpoint pump discharge to the desired point of disposal.

CONCLUSIONS AND RECOMMENDATIONS

1. Gamma-ray logging should be carried out and a few additional test borings should be installed to clarify stratigraphic and hydraulic conditions in the southern and northeast sections of the site and to confirm the thickness of the clay confining bed.

2. Selected wells near the landfill, Well 11, Well BR, and well cluster H should be resampled to recheck lead concentrations in groundwater.

3. An abatement system using wellpoints screened in the lower third of the water-table aquifer would be more effective and less costly than collector trenches or slurry walls. These wellpoints should be located within the center of the plume as well as along the eastern and the western edges.

4. The number of proposed wellpoints at the landfill may be reduced depending on a better definition of the water-table configuration in the northeastern area. However, if the number of wellpoints is maintained as presented in this report, no problem of subsidence at the landfill is anticipated because the drop in head is about 1.0 foot.

5. Pilot testing of the wellpoint system should be undertaken to develop a water quality data base required for selection of the optimum treatment scheme.

6. If water quality data developed during pilot testing indicate that treatment by dilution is feasible, the availability of groundwater from deeper sands of the Magothy-Raritan should be investigated.

Respectfully submitted,

GERAGHTY & MILLER, INC.

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May 2, 1983

APPENDIX A

NL INDUSTRIES, PEDRICKTOWN, NEW JERSEY

GEOLOGIC LOGS

Geologic Logs

Description	Depth (feet below land surface)	Thickness (feet)
Well 10		
Sand, brown, fine; with a trace of silt	0 - 4	4
Sand, gray, fine	4 - 14	10
Sand, gray, fine to coarse	14 - 20	6
Sand, gray-white, fine to coarse; with silt, clay and occasional lenses of clayey sand	20 - 28	8.0
Clay, red-pink, white, mottled; with silt	28 - 33	5
Silt, white; with some clay and very fine sand	33 - 41	8
Sand, gray-white, very fine; with silt and occasional lenses of silty clay	41 - 49	8
Sand, red-brown, fine to medium; with occasional gray-white lenses of sandy silt	49 - 63	14
Clay, red-pink, white, mottled; with silt	63 - 66	3
Sand, red-brown, fine to coarse	66 - 73.5	7.5
Clay, red, brown and white, mottled; with silt	73.5 - 79	5.5
Sand, red-brown, fine to medium; with lenses of silt, clay and gray sand	79 - 82	3
Well 11		
Topsoil	0 - 0.5	0.5
Sand, brown, fine to medium; with silt	0.5 - 3	2.5
Silt, gray; with very fine sand and some clay	3 - 4.5	1.5
Sand, brown, fine to medium; with silt, lense of coarse sand with occasional fine gravel	4.5 - 9	4.5
Sand, red-brown, medium to coarse; with lenses of sandy clay	9 - 15.5	6.5
Sand, gray, fine to medium; with a trace of fine gravel	15.5 - 19	3.5
Sand, white-gray, fine to medium; with silt and occasional lenses of clayey silt with fine sand	19 - 28	9

Description	Depth (feet below land surface)	Thickness (feet)
Well 11 (continued)		
Clay, red-pink, white, mottled	28 - 34	6
Sand, red-brown, fine to coarse	34 - 39	5
Sand, light brown, medium to coarse	39 - 44	5
Sand, light brown, fine to medium	44 - 54	10
Clay, white; with silt and a trace of fine sand, lenses of clayey silt	54 - 59	5
Well HD		
Sand, brown, fine; with silt	0 - 4	4
Sand, gray-white, fine to medium; with silt	4 - 7	3
Silt, gray-white; with lenses of pink-red, white, mottled silty clay, gray-white silty fine sand and red-brown silty fine sand	7 - 21.5	14.5
Sand, yellow-brown, fine; with silt	21.5 - 29	7.5
Sand, gray-white, fine to medium; with silt and occasional gray silty clay lenses	29 - 38	9
Silt, gray-white, brown, mottled; with clay	38 - 41	3
Well ID		
Sand, brown, fine; with silt	0 - 3	3
Sand, light brown, fine; with silt and lenses of fine silty sand	3 - 8	5
Sand, gray-white, fine to medium; with silt	8 - 11.5	3.5
Silt, dark gray; with clay and lenses of fine sand	11.5 - 19	7.5
Sand, gray-white, fine to medium	19 - 24	5
Sand, gray-white, fine to coarse; with some silt and clay	24 - 28	4
Sand, gray-white, fine to medium; with some silt and clay lenses	28 - 37.5	9.5
Clay, red-pink and brown, mottled; with silt	37.5 - 41.5	4

Description	Depth (feet below land surface)	Thickness (feet)
Well JD		
Sand, light brown, fine to medium	0 - 4	4
Sand, gray-white, fine to medium; with silt and occasional lenses of clayey sand	4 - 9	5
Sand, gray-white, fine to coarse; with silt, and occasional lenses of sandy clay	9 - 20	11
Sand, gray-white, fine to coarse; with silt, occasional lenses of sandy clay and fine gravel	20 - 23	3
Sand, white, brown, mottled, very fine; with clay, and lenses of sandy clay, with silt	23 - 25	2
Clay, red-pink, white, mottled; with silt	25 - 27	2
Well KD		
Silt, dark brown; with fine sand and organic matter	0 - 5.5	5.5
Sand, gray, fine; with some silt	5.5 - 8.5	3
Sand, gray-white, fine to coarse; with a lense of green-brown mottled very fine clayey sand with some silt	8.5 - 18	9.5
Sand, gray-white, fine to medium; with occasional lenses of sandy silt	18 - 26.5	8.5
Clay, red-pink, white, mottled; with some silt	26.5 - 29	2.5
Well LD		
Topsoil	0 - 0.5	0.5
Sand, light brown, fine	0.5 - 4	3.5
Sand, brown, fine; with some silt	4 - 9	5
Sand, gray-white, fine to medium; with silt and lenses of sandy clay	9 - 17	8
Clay, red-pink, brown, white, mottled; with some silt	17 - 19	2

Description	Depth (feet below land surface)	Thickness (feet)
Well MD		
Topsoil	0 - 0.5	0.5
Sand, light brown, fine; with silt	0.5 - 6	5.5
Silt, gray; with very fine sand and some clay	6 - 10.5	4.5
Sand, brown, fine; with silt	10.5 - 14	3.5
Sand, yellow-brown, fine to medium; with some silt	14 - 17	3
Silt, red-pink; with come clay and very fine sand	17 - 19	2
Well ND		
Topsoil	0 - 0.5	0.5
Sand, light brown, fine to medium; with a trace of silt	0.5 - 5	4.5
Sand, gray-brown, fine to medium; with a trace of silt	5 - 9	4
Sand, gray-white, fine; with silt and clay and lenses of sandy clay	9 - 14	5
Sand, gray-white, fine to coarse; with silt and clay and occasional lenses of sandy clay	14 - 21.5	7.5
Clay, red-pink and white, mottled; with silt	21.5 - 22	0.5
Well OD		
Topsoil	0 - 0.5	0.5
Sand, light brown, fine to medium; with some silt	0.5 - 7.5	7
Sand, brown, fine to coarse; with a gray-violet silt lense	7.5 - 11.5	4
Sand, gray-white, fine to medium; with some silt and occasional lenses of sandy clay	11.5 - 24	12.5
Sand, gray-white, fine to coarse; with some fine gravel and lenses of sandy clay	24 - 35.5	11.5
Clay, red-pink; with some silt	35.5 - 37	1.5

Description	Depth (feet below land surface)	Thickness (feet)
Well PD		
Topsoil	0 - 0.5	0.5
Sand, brown, fine to medium; with silt	0.5 - 3	2.5
Silt, gray; with very fine sand and some clay	3 - 4.5	1.5
Sand, brown, fine to medium; with silt and a lense of coarse sand with occasional fine gravel	4.5 - 9	4.5
Sand, red-brown, medium to coarse; with lenses of sandy clay	9 - 15.5	6.5
Sand, gray, fine to medium; with a trace of fine gravel	15.5 - 19	3.5
Sand, white-gray, fine to medium; with silt and occasional lenses of clayey silt with fine sand	19 - 28	9
Clay, red-pink, white, mottled	28 - 30	2
Well QD		
Sand, brown, fine to medium; with silt	0 - 8	8
Sand, gray-white, fine to medium; with silt	8 - 14	6
Sand, gray-white, fine to coarse; with silt	14 - 22	8
Clay, red-pink, white, mottled; with silt	22 - 25	3
Well RD		
Topsoil	0 - 0.5	0.5
Sand, light brown, fine to medium; with a trace of silt	0.5 - 9	8.5
Sand, gray, fine to medium; with a trace of silt	9 - 16.5	7.5
Clay, gray; with some silt and occasional lenses of fine silty sand	16.5 - 34	17.5
Silt, red, with some white mottling; sand, very fine and some clay	34 - 40.5	6.5

Description	Depth (feet below land surface)	Thickness (feet)
Well SD		
Sand, brown very fine; with some silt, trace of clay	0 - 3	3
Sand, brown, fine to medium; with some silt, plastic debris from battery casing	3 - 14	11
Sand, gray-white, fine to coarse; with silt	14 - 20	6
Sand, gray-white, fine to coarse; with occasional lenses of silty clay	20 - 28	8
Clay, red-pink, white, mottled; with some silt	28 - 30	2
Well T2		
Fill, sand, brown, fine to medium; silt, black, with plastic pieces from batteries	0 - 3	3
Sand, brown, fine to medium	3 - 9	6
Sand, gray, fine to medium; with some silt and a trace of fine gravel	9 - 14	5
Sand, gray, fine; with some silt and a trace of fine gravel	14 - 22	8
Sand, gray-white, fine to coarse; with some fine gravel	22 - 23	1
Clay, red-pink, white, mottled; with silt	23 - 27	4

APPENDIX B

Pumping Test Data

NL Industries, Pedricktown Plant Site,

New Jersey

APPENDIX B

Pumping Test Data at NL Industries, Pedricktown Plant Site, New Jersey, Drawdown in Pumping Well T4, March 8, 1983, (Pumping rate = 7 gpm).

Time (min.)	Depth to Water Level (ft)	Time (min.)	Depth to Water Level (ft)
0	5.95	50.	17.2
0.5	8.20	55.	17.25
1.0	12.80	60.	17.25
1.5	14.0	70.	17.2
2.0	14.6	80.	17.2
2.5	14.6	90.	17.3
3.0	15.0	110.	17.3
3.5	15.3	120.	17.5
4.0	15.4	140.	17.4
4.5	15.5.5	160.	16.6
5.0	15.7	190.	16.43
6.0	16.1	221.	16.86
7.0	16.2	240.	16.65
8.0	16.8	270.	16.6
9.0	16.7	300.	16.59
10.	16.6	330.	16.5
12.	16.75	360.	16.43
14.	16.8	390.	16.38
16.	16.9	424.	16.55
18.	16.9	486.	16.9
20.	16.95	544.	17.0
22.	16.9	615.	16.9
24.	17.0	734.	16.6
26.	17.04	860.	16.7
28.	17.00	967.	16.6
30.	17.15	1080.	16.46
35.	17.2	1200.	15.93
40.	17.2	1320.	15.6
45.	17.2	1430.	15.7
		1465.	15.75

Recovery in Well T4

Time (min.)	Depth to Water Level (ft)	Time (min.)	Depth to Water Level (ft)
.25	14.7	50.	6.34
.5	12.4	55.	6.34
.75	10.9	60.	6.31
1.0	10.2	65.	6.31
1.5	9.3	70.	6.3
2.0	8.7	80.	6.3
2.5	8.35	90.	6.26
3.0	8.1	100	6.25
3.5	7.9	110.	6.23
4.0	7.73	120.	6.25
4.5	7.6	150.	6.21
5.0	7.5	210.	6.2
6.0	7.3	270	6.17
7.0	7.2		
8.0	7.05		
9.0	7.0		
10.	6.9		
12.	6.75		
14.	6.7		
16.	6.65		
18.	6.6		
20.	6.65		
22.	6.55		
24.	6.51		
26.	6.48		
28.	6.45		
30.	6.41		
35.	6.4		
40.	6.38		
45.	6.34		

Pumping Test Data at NL Industries, Pedricktown Plant Site, New Jersey

Observation Well T2-1, March 8, 1983; distance from pumping well = 10 feet

Drawdown

Time (minutes)	Depth to Water Level (feet)
0	10.24
1	10.91
2	11.76
3	12.51
5	13.15
11	13.90
17	14.06
20	14.07
37	14.29
61	14.35
72	14.41
81	14.44
93	14.45
140	14.46
152	14.46
169	14.36
172	14.27
177	14.25
187	14.23
300	14.21
360	14.21
420	14.18
487	14.18
552	14.18
616	14.18
625	14.18
636	14.18
762	14.23
868	14.23
981	14.23
1,041	14.12
1,084	14.11
1,100	14.10
1,110	14.09
1,132	14.07
1,152	14.05
1,221	14.03
1,243	14.03
1,266	13.94
1,283	13.91
1,329	13.72

Recovery

Time Since Pumping Stopped (minutes)	Depth to Water Level (feet)
0	13.84
1	13.66
1.9	13.13
2	12.58
2.5	12.28
4	12.02
5	11.81
6	11.66
7	11.45
8	11.43
9	11.16
11	11.1
12	11.03
14	10.96
15	10.92
17	10.88
19	10.83
21	10.78
23	10.75
25	10.71
27	10.7
29	10.68
30	10.68
32	10.65
35	10.63
40	10.61
45	10.6
50	10.58
60	10.53
70	10.52
80	10.5
90	10.49
150	10.48
110	10.48
120	10.47
150	10.45
210	10.42
273	10.42

Pumping Test Data at NL Industries, Pedricktown Plant Site, New Jersey

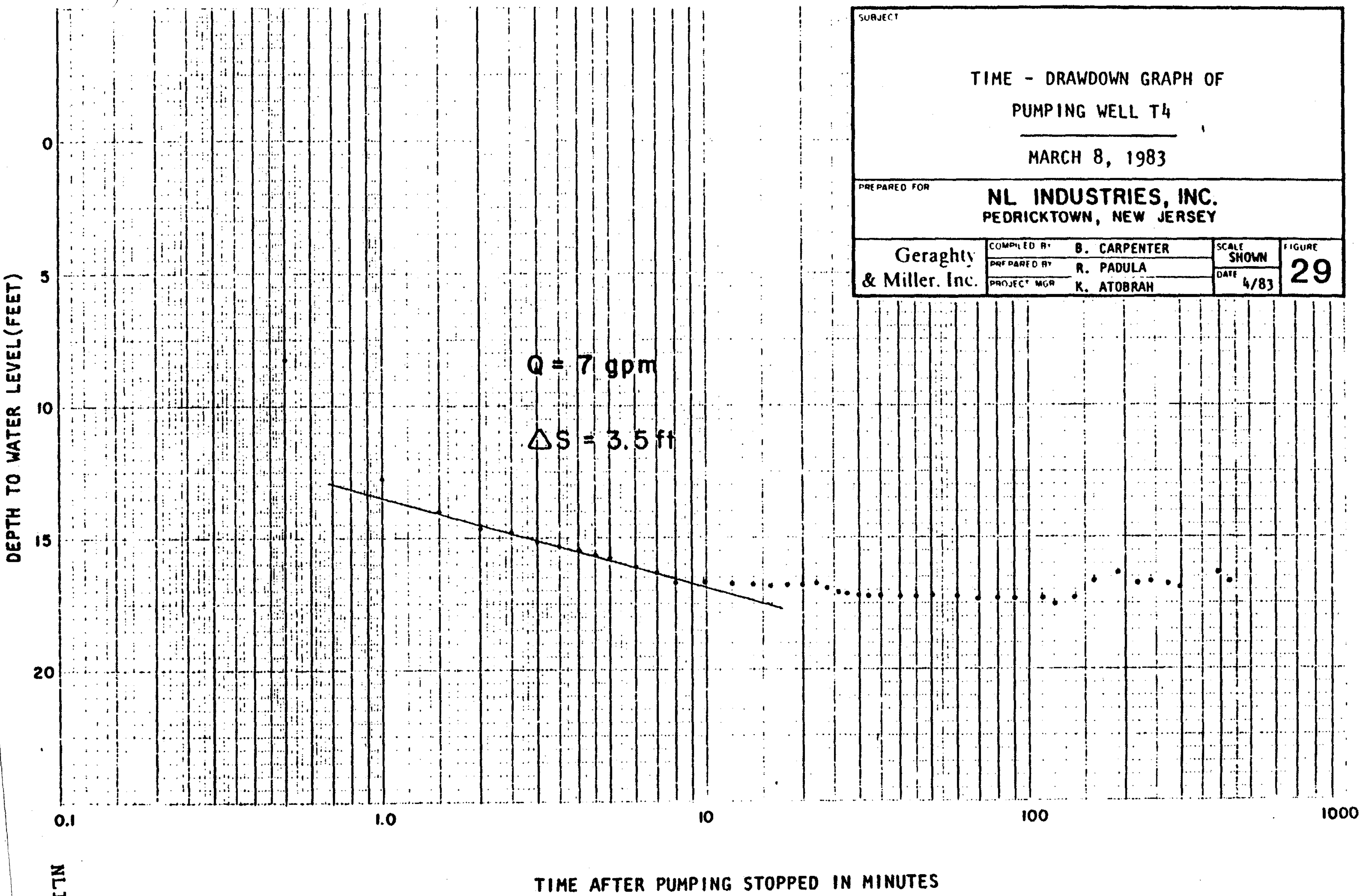
Observation Well T2-3, March 8, 1983; distance from pumping well = 35 feet

Drawdown: Time (minutes)	Drawdown: Depth to Water Level (feet)	Recovery: Time Since Pumping Stopped (minutes)	Recovery: Depth to Water Level (feet)
0	5.62	0	6.50
1	5.83	1	6.48
2	5.92	2	6.31
5	6.11	3	6.26
7	6.26	6	6.18
10	6.31	7	6.15
14	6.37	10	6.11
15	6.39	13	6.07
38	6.47	14	6.05
62	6.51	16	6.04
73	6.57	18	6.02
90	6.59	20	6.01
195	6.52	30	5.94
330	6.52	35	5.91
499	6.60	41	5.89
558	6.48	46	5.89
606	6.49	51	5.89
610	6.49	56	5.88
732	6.49	61	5.88
745	6.48	71	5.87
791	6.50	81	5.86
965	6.50	91	5.84
986	6.51	101	5.82
1,123	6.50	111	5.81
1,135	6.50	121	5.80
1,185	6.50	155	5.79
1,387	6.43	223	5.72
		281	5.71

Pump Test Results at NL Industries, Inc., Pedricktown, New Jersey, Plant Site (March 8-9, 1983)

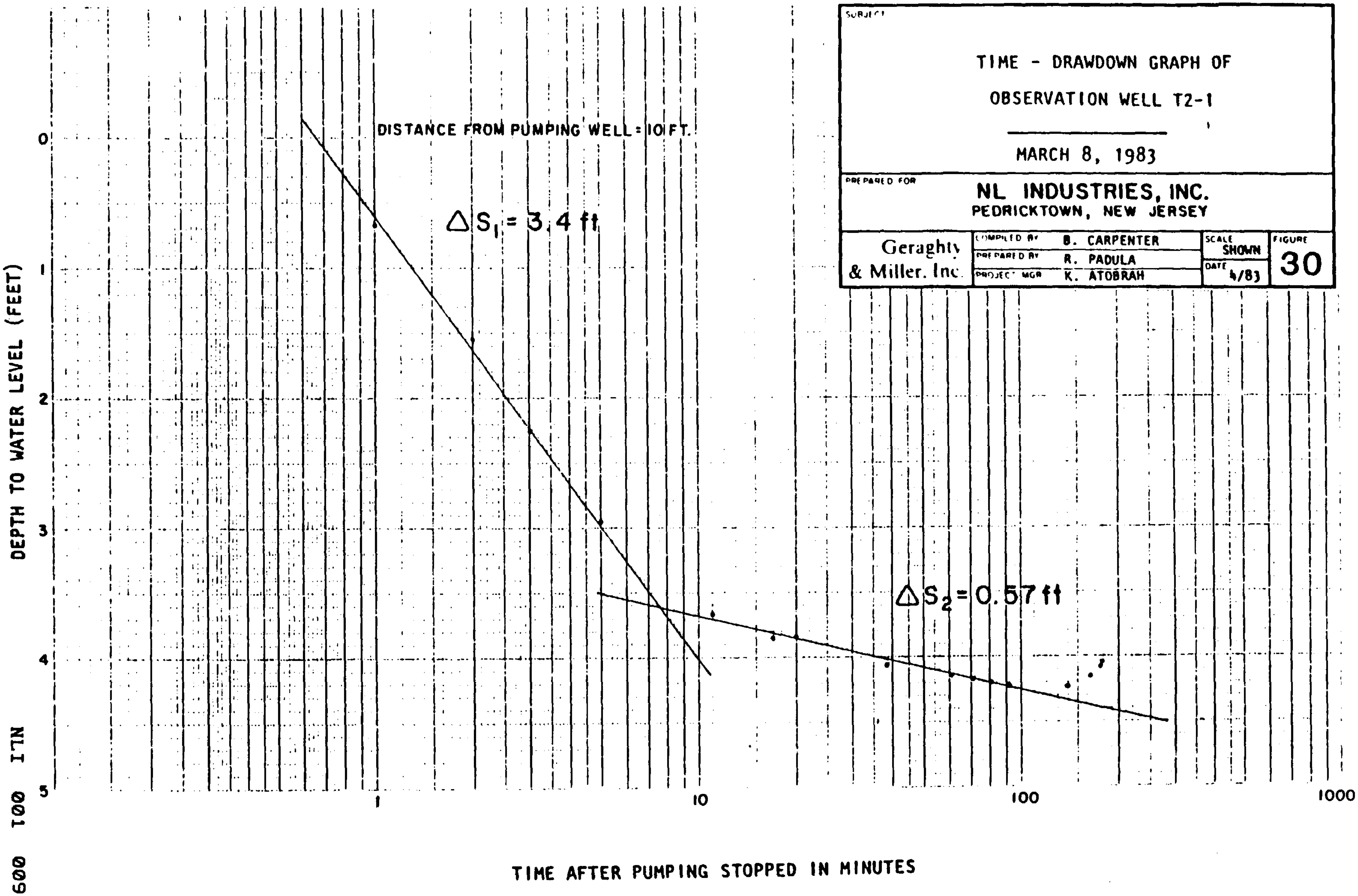
Pumping Rate = 7 gpm
Duration of Pumping = 24 hours

Well No.	Distance From Pumping Well r(ft)	Drawdown per Log Cycle of Time s(ft)	Transmissivity T(gpd/ft)	Storage Coefficient S	Hydraulic Conductivity K(gpd/ft^2)
Drawdown					
T4	0	3.5	528	-	29.33
T2-1	10	3.4	543.53	7.5×10^{-4}	30.2
		0.57	3,242.11		180.1
T2-3	35	0.42	4,400	2.3×10^{-4}	244.44
Recovery					
T4	0	6.8	252.35	-	14.02
		2.6	660		36.67
		0.6	2,860		158.89
T2-1	10	2	858	8.9×10^{-4}	47.67
T2-3	35	0.28	6,128.6	4.2×10^{-4}	340.47

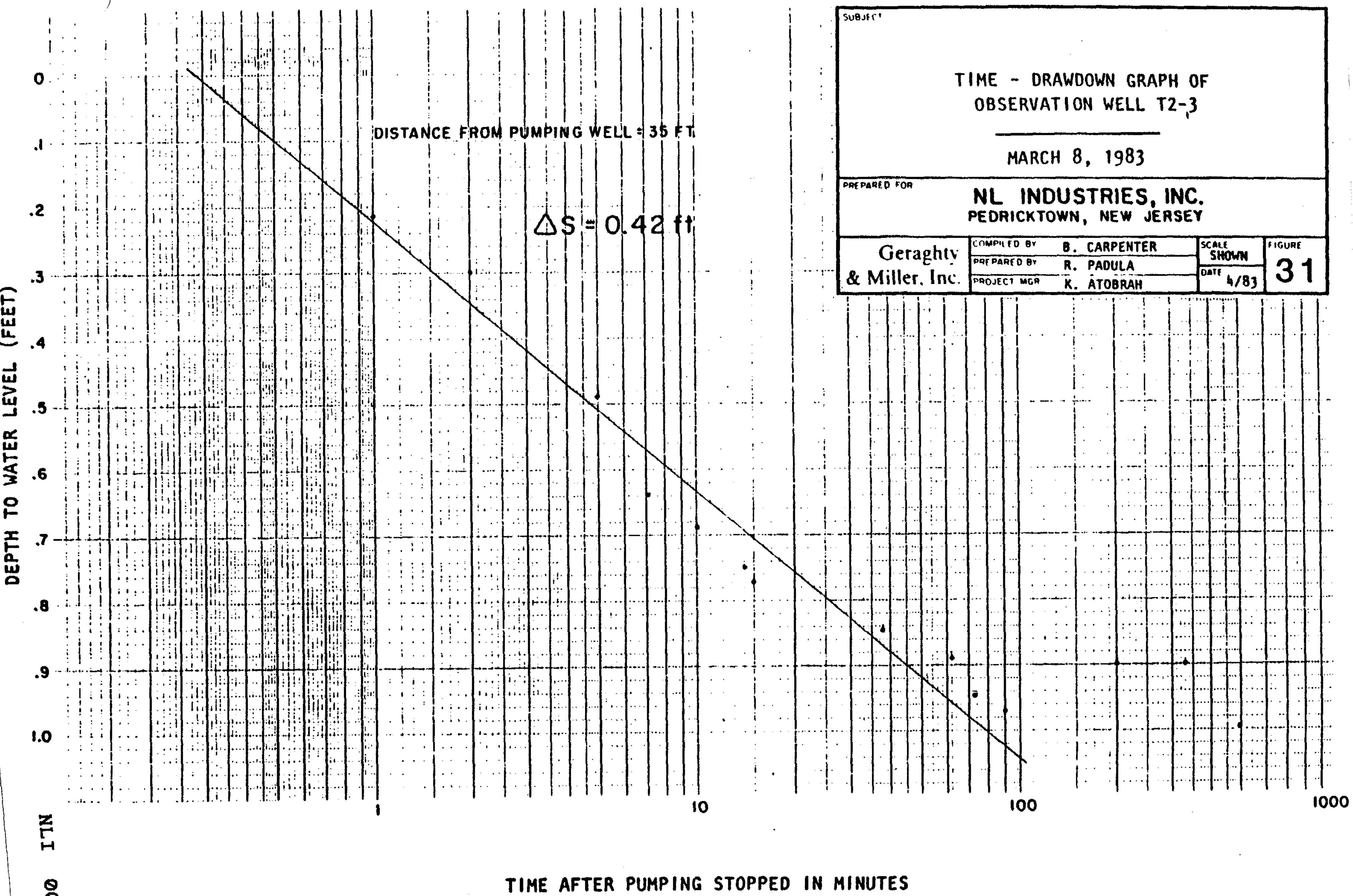


SUBJECT
TIME - DRAWDOWN GRAPH OF
PUMPING WELL T4
MARCH 8, 1983
PREPARED FOR
NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY
Geraghty & Miller, Inc.
COMPILED BY B. CARPENTER
PREPARED BY R. PADULA
PROJECT MGR K. ATOBRAH
SCALE SHOWN
DATE 4/83
FIGURE 29
Q = 7 gpm
ΔS = 3.5 ft
DEPTH TO WATER LEVEL (FEET)
0
5
10
15
20
0.1
1.0
10
100
1000
TIME AFTER PUMPING STOPPED IN MINUTES

NLI 001

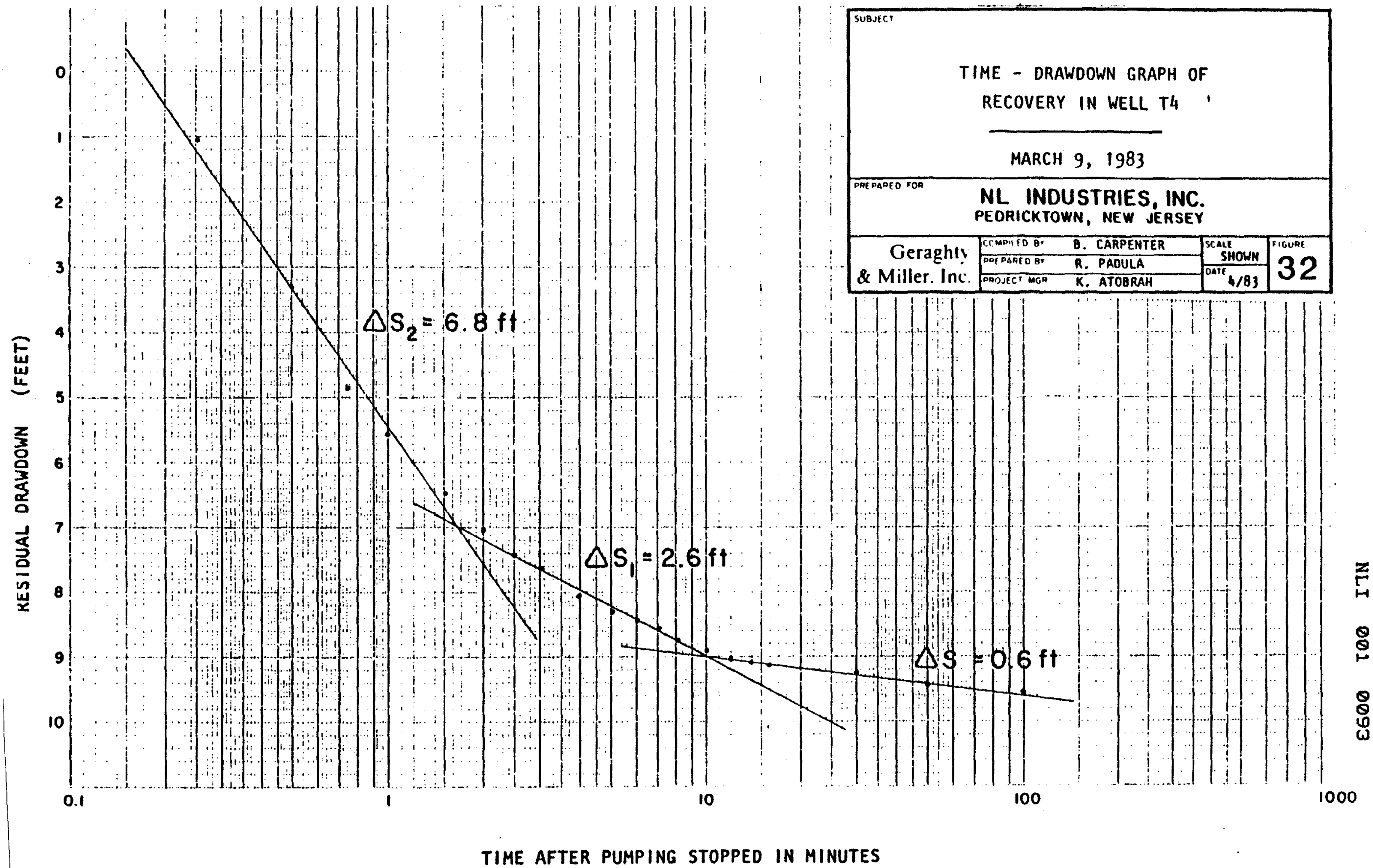

SUBJECT
TIME - DRAWDOWN GRAPH OF
OBSERVATION WELL T2-1
MARCH 8, 1983
PREPARED FOR
NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY
Geraghty & Miller, Inc.
COMPILED BY B. CARPENTER
PREPARED BY R. PADULA
PROJECT MGR K. ATOBRAH
SCALE SHOWN
DATE 4/83
FIGURE 30
DISTANCE FROM PUMPING WELL = 10 FT.
ΔS1 = 3.4 ft
ΔS2 = 0.57 ft
DEPTH TO WATER LEVEL (FEET)
0
1
2
3
4
5
1
10
100
1000
TIME AFTER PUMPING STOPPED IN MINUTES

NL 001 1600



SUBJECT			
TIME - DRAWDOWN GRAPH OF OBSERVATION WELL T2-3 MARCH 8, 1983			
PREPARED FOR: NL INDUSTRIES, INC. PEDRICKTOWN, NEW JERSEY			
Geraghty & Miller, Inc.	COMPILED BY: B. CARPENTER PREPARED BY: R. PADULA PROJECT MGR: K. ATOBRAH	SCALE: SHOWN DATE: 4/83	FIGURE: 31

NLI 001


SUBJECT
TIME - DRAWDOWN GRAPH OF
RECOVERY IN WELL T4
MARCH 9, 1983
PREPARED FOR
NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY
Geraghty & Miller, Inc.
COMPILED BY B. CARPENTER
PREPARED BY R. PADULA
PROJECT MGR K. ATOBRAH
SCALE SHOWN
DATE 4/83
FIGURE 32
ΔS2 = 6.8 ft
ΔS1 = 2.6 ft
ΔS = 0.6 ft
RESIDUAL DRAWDOWN (FEET)
0
1
2
3
4
5
6
7
8
9
10
0.1
1
10
100
1000
TIME AFTER PUMPING STOPPED IN MINUTES

NLI 001 0093

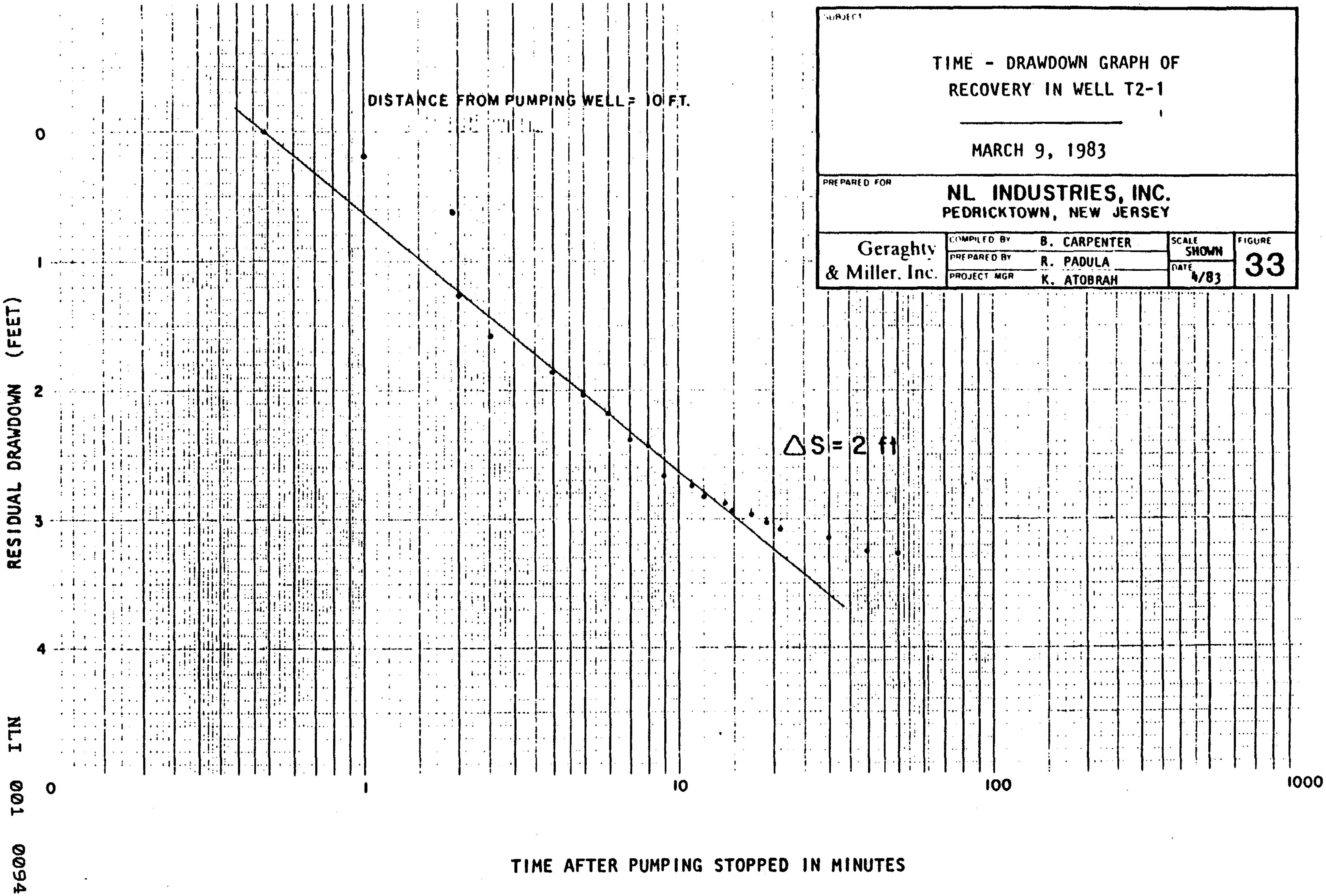
TIME - DRAWDOWN GRAPH OF
RECOVERY IN WELL T2-1

MARCH 9, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY	B. CARPENTER	SCALE SHOWN	FIGURE 33
	PREPARED BY	R. PADULA	DATE 4/83	
	PROJECT MGR	K. ATOBRAH		



NLI 001 0094

SUBJECT

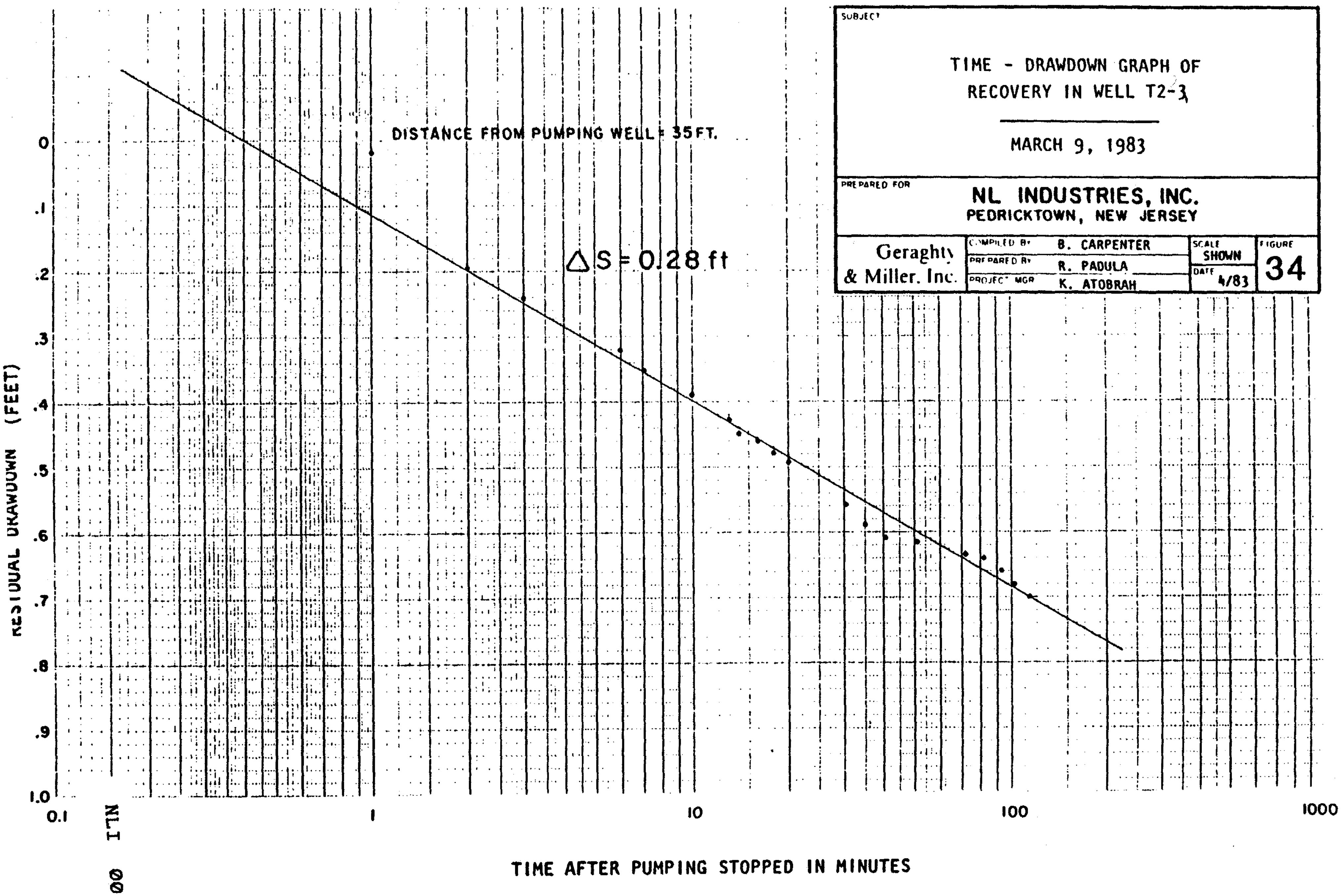
TIME - DRAWDOWN GRAPH OF RECOVERY IN WELL T2-3

MARCH 9, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY: B. CARPENTER	SCALE: SHOWN	FIGURE
	PREPARED BY: R. PADULA	DATE: 4/83	34
	PROJECT MGR: K. ATOBRAH		



NLI 001 0095

APPENDIX C

Results of Laboratory Permeability Tests

NL Industries, Pedricktown Plant Site,

New Jersey

Dames & Moore

6 Commerce Drive
Cranford, New Jersey 07016
(201) 272-8300
TWX: 710-996-5806 Cable address: DAMEMORE

December 27, 1982

NL Industries, Inc.
Environmental Control Department
P.O. Box 1090
Hightstown, New Jersey 08520

Attention: Mr. W. K. Weddendorf
Senior Environmental Engineer

Gentlemen:

In this letter/report we summarize the test results obtained from four (4) Laboratory Permeability Tests performed on soil specimens trimmed from two 2-7/8 diameter tube samples recovered by others at your Pedricktown plant site. The test program reported herein was planned in cooperation with your Mr. W. Weddendorf who was also kept informed of the program progress.

The attached table includes the test results obtained. All tests were performed in a Falling Head Permeability apparatus. All tested specimens were approximately 2.42 inches in diameter and one inch in thickness.

It is important to remind you that tested specimens may have been only partially saturated, which could result in laboratory values of permeability smaller than those prevailing under field conditions.

It was a pleasure serving NL again. If you have any questions regarding the contents of this report, please call us.

Very truly yours,

DAMES & MOORE

L. I. Stern / by MSA

L. I. Stern, P.E.
Partner

M. S. Abdelhamid

M. S. Abdelhamid, Ph.D.
Senior Engineer

RECEIVED
4 1983
ENVIRONMENTAL CONTROL

LIS/MSA:jp

Attachment

FALLING HEAD PERMEABILITY TEST RESULTS

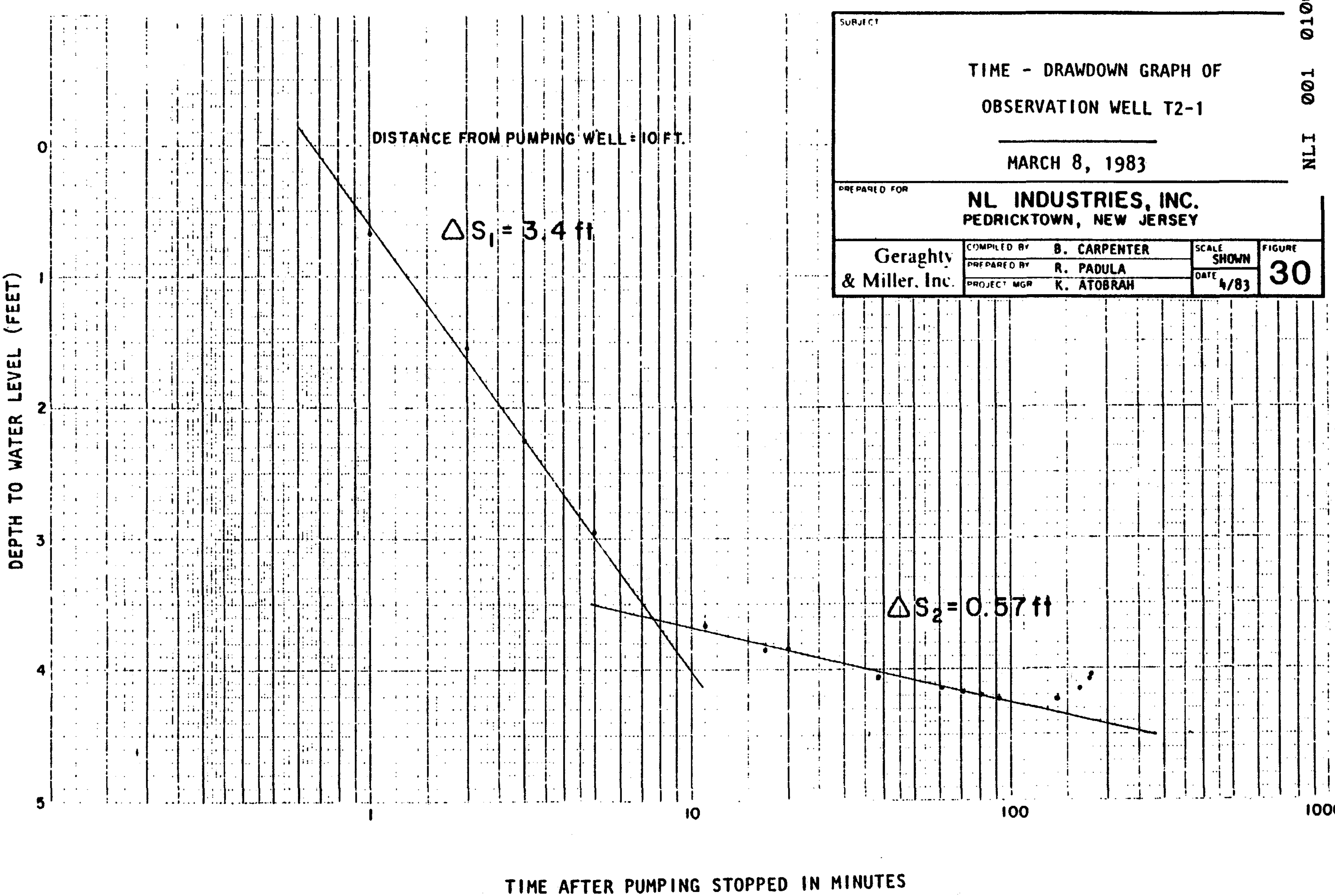
Well No.	Depth (feet)	Flow Direction	Permeability Coefficient (cm/sec)
10	32-34	Horizontal	2.97×10^{-8}
			3.06×10^{-8}
			2.99×10^{-8}
10	32-34	Vertical	6.46×10^{-8}
			6.86×10^{-8}
			6.87×10^{-8}
T 4	23-25	Horizontal	3.15×10^{-8}
			3.20×10^{-8}
			3.22×10^{-8}
T 4	23-25	Vertical	2.44×10^{-8}
			2.46×10^{-8}
			2.62×10^{-8}

APPENDIX D

Groundwater Sampling Protocol

NL Industries, Pedricktown Plant Site,

New Jersey



SUBJECT

TIME - DRAWDOWN GRAPH OF OBSERVATION WELL T2-1

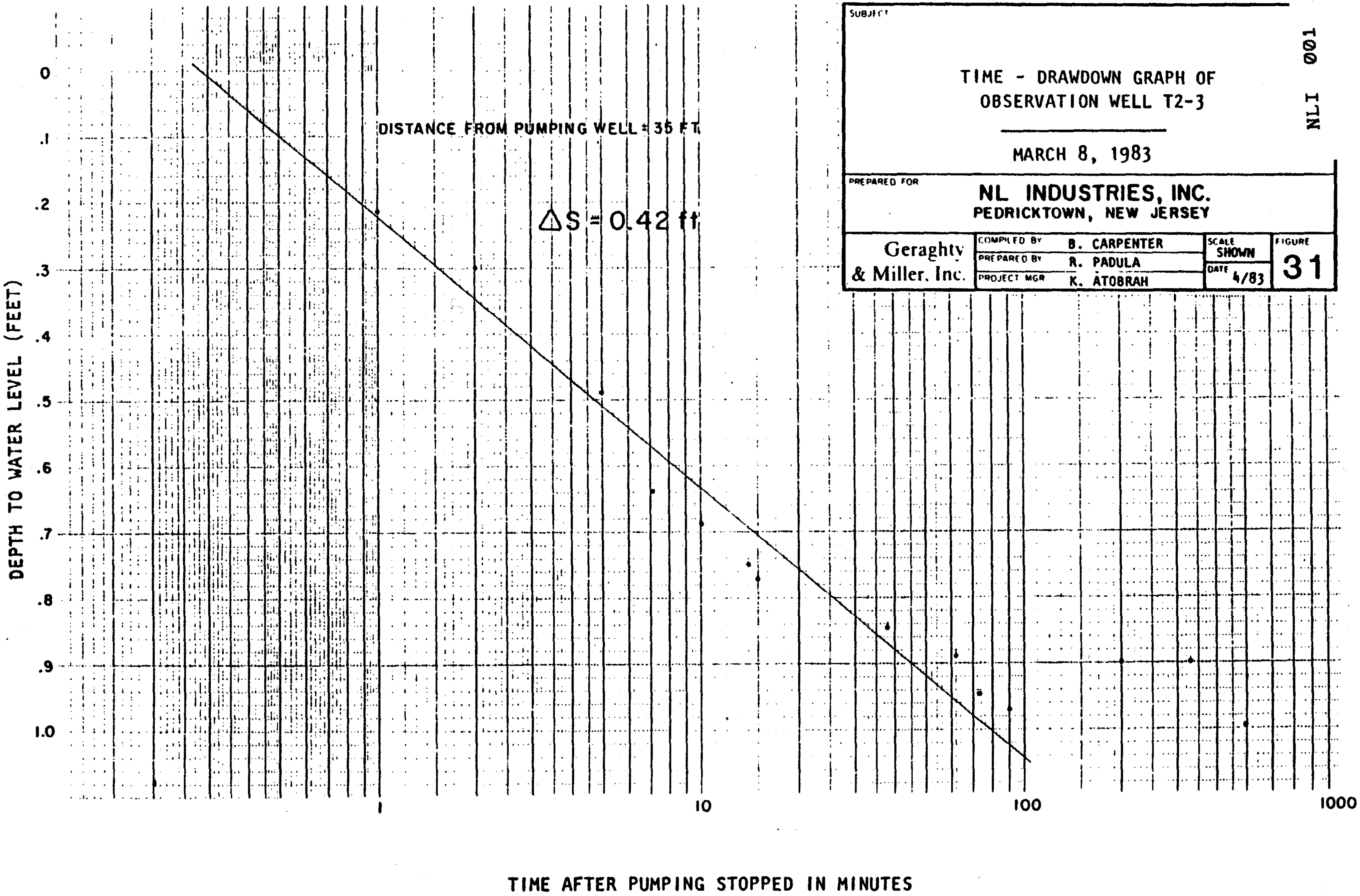
MARCH 8, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY B. CARPENTER	SCALE SHOWN	FIGURE 30
	PREPARED BY R. PADULA	DATE 4/83	
	PROJECT MGR K. ATOBRAH		

NLI 001 0100



SUBJECT

TIME - DRAWDOWN GRAPH OF
OBSERVATION WELL T2-3

MARCH 8, 1983

PREPARED FOR

NL INDUSTRIES, INC.
PEDRICKTOWN, NEW JERSEY

Geraghty & Miller, Inc.	COMPILED BY: B. CARPENTER	SCALE: SHOWN	FIGURE
	PREPARED BY: R. PADULA	DATE: 4/83	31
	PROJECT MGR: K. ATOBRAH		

NLI 001 0101

APPENDIX D

NL INDUSTRIES, PEDRICKTOWN, NEW JERSEY

GROUNDWATER SAMPLING PROTOCOL

Pumping Procedure

1. Pump type - ISCO pump (peristaltic)
2. Pumping rate - not to exceed 1 gpm
3. Pick-up to be about 5 feet below static water level
4. Prior to pumping, well depth and standing water level to be recorded.
5. Casing volume to be determined at .0043 gal/sq. in. = .16 gal/linear foot of 2-inch ID casing.
6. Minimum of 4 times casing volume to be pumped at 1 gpm or less, prior to sample collection
7. Temperature to be recorded during sample collection in °C.
8. Both deep and shallow well in each cluster to be sampled concurrently.
9. Pick-up to consist of plastic (Tygon) tubing.
10. New tubing to be used at each well sampled.

Sample Collection:

Initially, three glass bottles are to be filled per sample. One, 500 ml prepreserved with HNO_3, and two 1,000 ml non-prepreserved. Then one of the 1,000 ml bottles will be taken to onsite lab and 500 ml of sample will be vacuum filtered through .45 um filter. Filtered sample then will be poured in a second 500 ml bottle prepreserved with HNO_3. Filtering and preservative to be collected within one hour of sample.

Filtering Procedure

1. Install filter
2. Draw 250 ml of deionized H_2O through filter.
3. Draw 250 ml of 10 percent HNO_3 through filter.
4. Rinse container with the 10 percent HNO_3.
5. Draw 500 ml of deionized H_2O through filter.
6. Filter water sample.

Samples to be delivered to lab in afternoon of sampling date. If unable to deliver to lab, samples will be refrigerated overnight and delivered next day.

APPENDIX E

Description of the Model Used

NL Industries Pedricktown Plant Site,

New Jersey

APPENDIX E

DESCRIPTION OF THE MODEL USED AT NL INDUSTRIES PEDRICKTOWN PLANT SITE, NEW JERSEY

Introduction

The computer model used in this study was developed by Prickett and Lonnquist (1971)[1]. The model uses the finite difference numerical approach to approximate the equations that define ground-water flow. The model can account for heterogeneities and anistropy in the aquifer, as well as changes in transmissivity as a result of changes in saturated thickness, and for leakage to and from the first artesian aquifer. The model includes modifications to accommodate dewatering from, and recharge to the aquifer at any node of the discretization. Model output is in the form of generated heads useful for the construction of water-table maps.

The model was constructed and calibrated utilizing both published and field collected system-description data. Values describing subsurface geology, head and flow relationships, recharge, leakage through the confining clay layer, and coefficients defining the water-bearing characteristics of the aquifer were used to approximate average water-levels as interpreted from field measurements.

The probable changes to the ground-water system caused by the abatement alternatives have been described using the calibrated numerical model.

1) Prickett, T.A. and Lonnquist C.G., 1971, "Selected Digital Computer Techiques for Ground-Water Resource Evaluation" Illinois State Water Survey, Bulletin 55.

Model Description

To be able to simulate the ground-water system, the model has to contain elements that include the definition of the hydrogeologic units, the geometry of the flow system, aquifer characteristics, boundary conditions, and the stresses on the system. These data are used to numerically simulate ground-water head and flow relationships in the model so that stresses on the groundwater system can be simulated, described, and evaluated.

Data Base

The water-table aquifer in the study area is comprised of fine to coarse, silty sand. Existing data from published records, driller's logs, information from the files of Leggette, Brashears & Graham (LGB) and field work measurements carried out by Geraghty & Miller, Inc. was used to define aquifer parameters and model limitations.

Coefficients of permeability (K) for the model were estimated to range from 75 gpd/sq ft (gallons per day per square foot) to 325 gpd/ft. The unconsolidated material is typically variable and stratified, and the permeability values assigned are comparable to those based on driller's logs and field pumping tests.

The transmissivity parameter (T) is dependent upon the permeability (K) of the aquifer and the saturated thickness (b), and is calculated from the relationship $T = Kb$. Saturated thickness values are obtained by subtracting the elevation of the top of the clay confining bed from the water-table elevation. The model is set up to allow for changes in transmissivity in response to changes in water levels (permeabilities being a constant). The transmissivity values range from 1,000 gpd/ft (gallons per day per foot) to 8,000 gpd/ft.

In the study area recharge to the water-table aquifer occurs principally from infiltration of precipitation (rain and snow melt). A recharge rate of about 18 inches per year is used in the model, which corresponds to published estimated values.

Under certain hydraulic conditions, recharge may also occur from leakage from the first artesian aquifer. The rate of potential recharge (leakage) to the water-table system applied in the model is from 0.15 to 0.30 gpd/ft. This is based on the characteristics of the clay confining unit, the top of which ranges in elevation from 12 to 24 feet below mean sea level, has a thickness of 10 to 20 feet at the site, and an average vertical permeability of 1×10^{-3} gpd/sq ft.

Boundary Conditions

The modeled area encompasses about 2.81 million square feet (approximately 0.1009 sq. mi). Boundaries were imposed on the modeled system, beyond the limits of NL Industries property lines, so as not to inappropriately effect the system's head and flow characteristics.

Hydrogeologic boundaries were imposed on the modeled system by simulating them as constant-head boundaries, in order to maintain the observed water levels and maintain underflow through the ground-water reservior.

Model Calibration

The objective of model calibration is to compare the input data and the conceptual model of the aquifer to the real system to determine if the model is an accurate representation of the study area. This is generally demonstrated by using the model to simulate a period where model outputs can be compared to available water-level data. If the difference between observed and computed water levels exceeds specific limits, the input data and/or coefficents are modified (within the limits of the real system) to obtain the best match between observed and computed data.

The calibration of the model was accomplished by reproducing average water-level elevations recorded at the monitoring and observation wells during the field investigation. In addition, it is believed that the water-table map is representative of the general pattern of the groundwater flow at the site. For the most part the computed heads are found to be comparable to the observed field heads, and more importantly, the flow regimes of the two are analogous. The computer run was carried out to a period of about one year, a time period well beyond that needed to attain steady state (as evidenced in the pumping test). Steady state, means that there is no change in head with time and water is no longer being removed from storage. That is, water-level elevations do not change with time and an equilibrium is achieved.